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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS,

ABSTRACTS OF PAPERS,

AND

REPORTS OF THE PROCEEDINGS

OF

THE SOCIETY,

FROM NOVEMBER 1875 *TO NOVEMBER* 1876.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVI. *November* 12, 1875. No. 1.

PROF. J. C. ADAMS, F.R.S., President, in the Chair.

John Brise Colgrove, Esq., M.A., Rossall School, Fleetwood, was balloted for and duly elected a Fellow of the Society.

The University Observatory at Oxford. By the Rev. Prof. Pritchard.

It may be in the recollection of the Society that, exactly two years ago, I had the gratification of announcing the munificent intention of the University of Oxford to build and maintain an Observatory for researches connected with Astronomical Physics, and for the promotion of the study of the various branches of practical and philosophical astronomy among the members of the University. I have now the still further pleasure of communicating to the Society the completion of the undertaking in all its details.

With one exception, no great alteration has been made in the proposed construction of the building as detailed in the communication printed in the *Monthly Notices* of December 1873.

The exception referred to consists in the arrangements of the shutters in the revolving domes. The difficulties involved in the successful construction of such shutters is only too well known to astronomers, whether professional or amateur. It was publicly stated at a recent meeting of the Institute of British Architects by one of the most eminent and experienced

of its members, and I believe the dictum had already been generally received among ourselves, that the astronomical necessity of an Observatory, and the æsthetic requirements of architecture, are incompatible; it was also added that ornamental crestings on the top of the revolving roofs were impossibilities. Happily the impossible problem has been solved at Oxford; and to Mr. Charles Barry must be assigned the honour, be it great or little, of having harmonised the claims of architecture with the necessities of practical astronomy.

The very ingenious attempt made by the Engineer (not the Architect) of the Oxford Observatory domes, to construct a flexible shutter of corrugated steel capable of being rolled up into a box, on experience failed entirely. Had this able engineer been spared to his profession, he would probably have succeeded on a further trial; but as it was, the difficult task of devising some practicable substitute devolved upon the Director of the Observatory. The problem was to devise a form of shutter which should be practically applicable to a revolving dome of handsome form, and that form neither hemispherical nor cylindrical.

After some consideration the solution of this problem turned out to be, as usual, something unexpectedly simple. The idea which suggested itself was to divide the shutters into three portions, *bending* them to the form of the dome (made approximately cylindrical at the opening or slip), and then sliding them up and down and over each other in their respective grooves, like the overlapping lights of a large greenhouse. The shutters, it was hoped, would be heavy enough to descend by their own weight, and each, or all of them together, could be drawn up into any required portion of the slit, and there maintained by ordinary sash-lines, winches, and lazy-pullies. This plan has been executed with perfect success; the system of shutters moves easily, causes no trouble, has proved perfectly watertight during the recent deluge of rains, and affords the means of excellent ventilation. The annexed Plate (reduced from an enlarged photograph now presented to the Society) of Mr. Charles Barry's design, will enable the members to form their own judgment as to the compatibility of elegant form with the necessities of an astronomical revolving roof.*

I now gladly turn to subjects of greater scientific interest, and probably more nearly touching the sympathy of the Royal Astronomical Society. Mr. Grubb's large equatoreal refractor proves, on experience, to be a very admirably constructed instrument. A photograph thereof shall be submitted to the judgment of

* It should be understood that in the present instance, there were especial reasons for studying external appearance, on account of the beauty of the Park in which the University allowed the Observatory to be erected. A revolving roof of the usual form, either of a hemisphere or of a drum, would have been regarded as an intolerable disfigurement of the place.

the Society at its next meeting. The object-glass is 12¼ inches clear aperture, and about 176 inches focal length: its optical qualities have been pronounced excellent by several competent judges who have examined its performance. The mounting of this large telescope has excited our admiration and our gratitude as often as we have had occasion to use it; its motion is steady and easy, and, when clamped, it is firm.

The contrivances for illuminating the divisions of the declination circle (of 30 inches diameter) and the field of view, the latter with either dark or bright wires, are ingenious and successful. The gas jet suspended from the extremity of the perforated declination circle, performs all this necessary work: it effectively illuminates also the position circle of nine inches diameter, which is permanently attached to the observing end of the telescope; alterations of intensity of light and colour are within the easy command of the observer.

The declination circle is read at the observing end by means of two long microscopes furnished with micrometer eye-pieces; while a third and contiguous long microscope, with a wide field as a rough reader, allows an easy method of setting the instrument in north polar distance. In the first instance, the flexure of the long microscope tubes (probably an inherent concomitant of such contrivance) proved an intolerable annoyance; but the defect has been effectually remedied by the attachment of a small platinum plate engraved with a fiducial line, which rotates with the tube of the telescope, closely to the plane of the divisions of the circle. Guided by our own experience, we can safely recommend this method in the future construction of very large instruments.

The clamping of the instrument in both elements is effectually made by means of a probably novel, and certainly very ingenious arrangement, of cylindrical male and female V-pieces, which are brought into contact by a small rod close to the observer's hand.

The driving clock does its work probably as well as any other existing clock; it is, comparatively, excellent, but not faultless. I am informed that Mr. Grubb has discovered a remedy of the defects by means of electrical connection with the normal clock of the Observatory, and that the experiment is now being made at Dr. Huggins's Observatory at Tulse Hill. If it there succeeds, we shall hope to adopt it at Oxford.

The contrivances for moving the telescope through small arcs while attached to the driving-clock, and for changing the rate for observations of the Moon, are perfectly satisfactory.

There are two subsidiary telescopes, of four inches, and two and a quarter inches, aperture respectively, attached to the tube. These we regard by no means in the light of mere finders, but each of them has its own illuminating apparatus, and each is adapted to all the micrometers and eye-pieces of the larger tube. The finder proper, when such aid happens to be required, consists of

a pair of rifle-sights applied to the tube of the four-inch telescope.

There are three micrometers: two of them are filar micrometers, and the third is a double image micrometer by Troughton and Simms, and forms one out of the many generous gifts of Dr. De La Rue.

Finally, the instrument, independently of its many eye-pieces, whether solar or otherwise, is furnished with a Star spectroscope of unusual excellence by Mr. Grubb; a second, by Mr. Browning, is the gift of Dr. De La Rue; while the complement is completed by a Sun spectroscope admitting of the dispersion of either four prisms of sixty degrees, or of eight, or of twelve, at the desire of the observer. This latter powerful but simple instrument, by Grubb, I hope to submit to the inspection of the Society at its next meeting.

The devising and construction of an efficient observing chair always occasions some trouble and anxiety. I have myself adopted the simple idea of a set of five steps, some forty-two inches wide, terminating with a rather broad platform and rails at the top: the whole moves on large castors, and can be pushed into any required position with the finger. Various cushions and hassocks lie on the steps of this machine, in order to vary by slight degrees the height of the observers as they sit to their work: I say observers, because it is sometimes of advantage, and to us often so, for two observers to work simultaneously on the same phenomenon with two telescopes of different apertures.

The refracting telescope, with its appendages thus described, occupies the larger or western dome. The eastern, or De La Rue dome, contains that gentleman's munificent gift to the University, and we can only hope it may be destined to effect some work worthy of its former reputation. Both these domes rotate on a simple adaptation of Smeaton's line ring. A child may easily turn either of them.

The annex between the two domes is divided into two portions: they contain one of Dr. De La Rue's large reflectors mounted as an altazimuth, with a small motion near the meridian, a five-feet transit instrument, and three smaller instruments mounted on their stone pedestals, and intended for educational purposes among the members of the University.

The rooms under the two dome rooms already described are devoted to a computing room, a private room for the Director, and a photographic room together with its dark chamber. A somewhat lofty basement underlies all these rooms, and the whole building is lighted with gas. In one of the compartments of the basement there are placed Dr. De La Rue's polishing machine for telescope mirrors, and Foucault's apparatus for testing their figures.

I need scarcely repeat that the Observatory and its instruments are not designed so much for meridional observations as for re-

searches connected with what may properly be termed Astronomical Physics.

Nevertheless, we are at all times prepared to devote the large apertures of the instruments to any desirable purposes to which they appear adapted: and although the Observatory has only been finally completed in all its details within the last few days, a considerable set of observations of six of the satellites of Saturn have been taken, which we trust will prove of some value, and will shortly be communicated to the Society.

In concluding the description of these really noble specimens of astronomical engineering, I cannot refrain from recording my admiration of the admirable manner in which Mr. Grubb has much more than merely fulfilled his contract with the University of Oxford. It has been one among many other happy results of the removal of ancient fiscal misarrangements, that English opticians have at length overtaken their eminent brother artists on the Continent. It is not now so much to Munich that it is necessary to resort for our largest and most perfect instruments; but gigantic observatories and colossal telescopes are at this moment in course of construction in the workshops of Dublin, intended to promote astronomical research in some of the chief cities of Continental Europe.

I may also, I trust, be pardoned for repeating a remark which I believe I have made in this Society before, to the effect that the artists and constructors of these admirable astronomical machines—admirable alike for their ponderous stability, for the smoothness of their motion, and for their adaptation to the most minute delicacy of accurate measurements—claim at our hands a meed of gratitude and honour scarcely if at all less than that which we so gladly accord to the illustrious astronomers who so successfully avail themselves of the mechanician's skill. And all honour be also paid to the enlightened munificence of the University of Oxford, who, notwithstanding their comparatively limited pecuniary resources, and the vast and ever-increasing variety of claims that are made upon them, have devoted so much encouragement and so considerable a sum to the cultivation of the science which so deeply engages our own sympathies. Dr. De La Rue also may be congratulated on the hitherto successful arrangements to which his own generosity gave the first impulse.

On the Preparations which are being made on the Continent for promoting Physico-Astronomical Observations. By Warren de La Rue, D.C.L., F.R.S.

It is scarcely necessary for me to tell the Fellows of the Royal Astronomical Society that their favourite branch of our science, namely, the Physics of Astronomy, is now engaging the earnest attention of foreign professional astronomers to a greater extent than obtained only a few years ago, and that grand preparations

are now being made at several continental State-Observatories to grapple with the important truths which can only be revealed by adequate instrumental appliances such, indeed, as are far beyond the reach of most private fortunes. It was a matter of satisfaction to me to learn that photographic Observatories are to be included in at least two of those Observatories, namely, in Paris and Vienna.

I was particularly impressed with the new Observatory in course of erection in the vicinity of Vienna, and I have thought that an account of it might have some interest for the Royal Astronomical Society; hence I have ventured on making this short communication respecting it.

The old Observatory is situated nearly in the centre of Vienna, in the midst of narrow bustling streets, closely overlooking house-tops and chimnies, and, consequently, quite unfitted for accurate astronomical work. It was founded in the year 1753, its first Director being M. P. M. Hell; it was rebuilt on the same ill-adapted site in the years 1826–27, under the direction of M. T. T. von Littrow, the father of the present Director, and was adapted and equipped by him to meet as far as possible the requirements of a modern Observatory; but even at that period the surrounding buildings must have greatly militated against satisfactory astronomical work.

The present Director, M. C. von Littrow, repeatedly urged upon the Austrian Government the desirability of removing the National Observatory to a more favourable position, and ultimately, in 1873, obtained the sanction of the Minister of Public Instruction (K. von Stremayer) for the building of an Observatory adapted in every respect to the present state of astronomical science.

Before deciding on the plan and equipment of the new Observatory, the Austrian Government wisely adopted the suggestion of M. von Littrow, and sent Prof. E. Weiss, First Assistant of the Observatory, to visit the public and private Observatories of England and America, and the workshops of the instrument-makers in these and continental countries.

From information thus gathered it was determined to ask the Government for a refractor of about 26 inches aperture as the principal instrument of the new Observatory; this necessitated a dome of 42 feet internal diameter, and formed the starting-point in the consideration of the general plan of the Observatory, which has been ably worked out by the architect, M. F. Fillner, under M. von Littrow's direction.

The site of the new Observatory is admirably chosen three miles to the north of the centre of the city: it consists of a plateau of between 14 and 15 acres, at an elevation of about 200 feet above the mean level of Vienna. The new Observatory is 330 feet long in the direction of north-south, and 240 feet in that of east-west. The foundation stone was laid in June 1874, and it is hoped that the building will be completed in 1877. Judging from the great progress which had been made when

I visited it in October, I believe that it will be ready to receive the instruments at that time. The buildings comprise the dwelling of the Director and apartments for the assistant astronomers. Although the personal comfort of the astronomers will be greatly promoted by residence within the walls of the Observatory, it would have been, in my opinion, preferable for the dwellings to have been detached, as the heated air emanating from them will be liable to disturb the definition of the instruments.

Fig. 1 represents the south front of the Observatory, the central entrance opening into the dwelling of the Director, which is to the south of the large dome—not, perhaps, the best position that could have been selected.

Fig. 1.

The large Equatoreal which is to occupy the central dome has been ordered of Mr. Howard Grubb, of Dublin, who has also been intrusted with the construction of the revolving dome intended to cover it, as well as that of the three smaller domes, two of which are situated east and west of the central dome, and are shown in figure 1. One of these domes will contain an equatoreal refractor of 12 inches aperture, ordered of Mr. Alvan Clark, of Cambridgeport, Mass., which will be finished about the end of 1876. These two instruments, together with a meridian circle having a telescope of 8 inches aperture, and augmented by the instruments already in the old Observatory, will constitute the first equipment of the new establishment. Later on it is intended to place in the third dome an equatoreal reflector specially adapted for photography, and also a prime vertical instrument in the room near the fourth dome, to the north of the central dome.

FIG. 2.

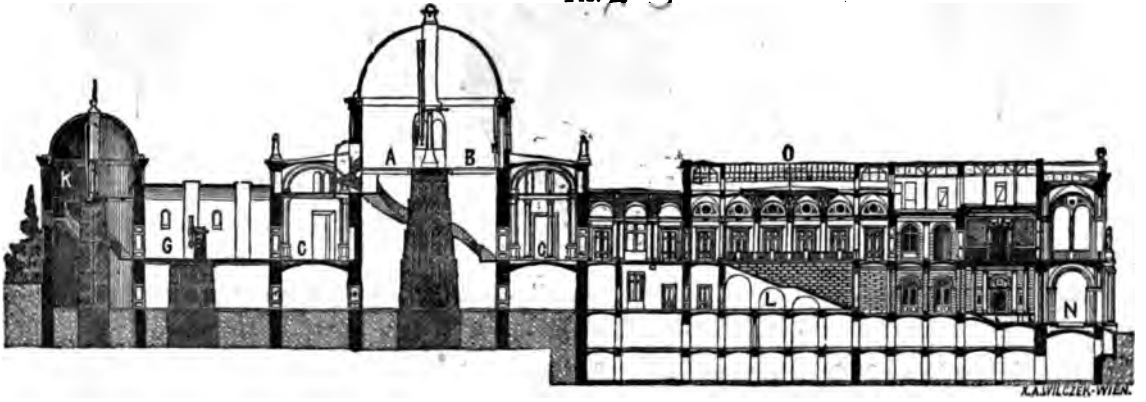
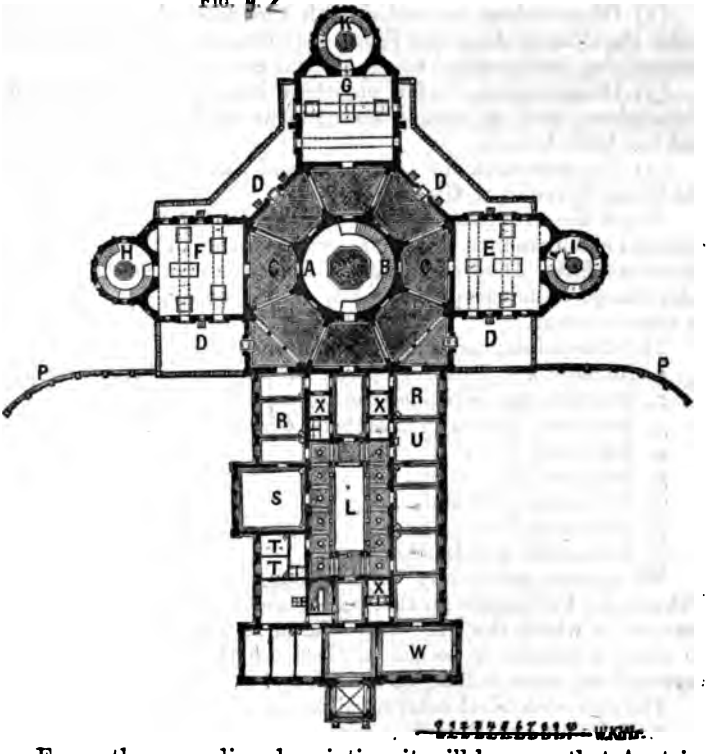


Figure 2, drawn on a smaller scale than Fig. 1, shows the general arrangement of the establishment in plan. A B is the great dome, 42 feet in diameter; this dome is surrounded at its lower portion by the central hall C C, which

will contain all the portable instruments. From this central hall access is obtained to the terraces D, adapted for observations with portable instruments or the naked eye. The rooms E and F will receive the meridian instruments, and in G is to be placed the prime vertical. The smaller domes, H, I, and K are each 25 feet in diameter: besides the instruments before spoken of, one of these domes will most probably be equipped with an altazimuth or a heliometer. The 12-inch Alvan Clark is to be used mainly and continuously for the determination of the position of the small planets and comets.

The connection of the dwelling-house with the Observatory is best shown in the section Fig. 3, which is on the same scale as Fig. 1. It will be seen that the first floor of the Director's house is on the same level as the ground floor of the Observatory; the apartments of the assistant Astronomers are on the ground floor. C C show the section of the gallery surrounding the ground floor of the great dome; L the section of the staircase. Referring again to Fig 2, W is the Director's house in plan; S and T T the library; U the lecture theatre; and lastly, R the offices.

FIG. 2



From the preceding description it will be seen that Austria

will not be left behind in the steps which are being taken to promote Physico-Astronomical observations; and I sincerely hope that our own Government will ere long adopt measures to ensure to England a fair chance of honourably competing in the advancement of that branch of Astronomical Science which the Fellows of this Society have done so much to promote mainly from their own individual resources.

On the State of the Reductions of their Observations of the Transit of Venus. By Lord Lindsay and Mr. Gill.

The observations accumulated during the Expedition are:

(1) Those connected with the geographical position of the station, Belmont, and the connection of that with neighbouring stations.

(2) Observations connected with the determination of the Solar Parallax by *Juno* and *Venus*, including the observations for ascertaining instrumental constants and corrections.

(3) Observations of a few objects of interest in the Southern Hemisphere, such as double stars; however, for this class we had but little leisure.

(4) The measurement of a base, and exact triangulation of the Great Pyramid of Gizeh.

As yet the reduction of this mass of observations has been confined chiefly to those that come under section (1). This section includes—First. Determinations of differences of longitude by interchange of telegraphic signals, and secondly, by transport of chronometers.

The determinations by telegraph are, between—

1. Belmont and Pamplemousse (Mr. Meldrum's Observatory).
2. Belmont and Solitude (the German Station).
3. Aden and Bombay (Chambers' Observatory).
4. Aden and Suez.
5. Suez and Alexandria.
6. Alexandria and Malta.
7. Malta and Berlin; and
8. Alexandria and Berlin direct.

We cannot sufficiently express our thanks to the various Telegraphic Companies for their excessive kindness and the liberal manner in which the lines were placed at our disposition over so great a length, or to the *employés* on those lines, who rendered all and most willing assistance and information.

The chronometrical determinations are, between—

1. Belmont and Pamplemousse Obs. 8 chron. } Double
2. Belmont and Solitude . . . 36 „ } runs.

3. Belmont and Mr. Neate's station in Rodrigues, 2 double runs.*

4. Belmont and Reunion . 1 run
5. Reunion and Seychelles. 1 „
6. Seychelles and Aden . 1 „
7. Mauritius and Aden . 1 „

} making Aden, Mauritius, 2 runs.

8. Aden and Suez, 2 runs, from 3 to 8, consisting of runs of 80 chronometers.

9. In Egypt. Mr. Gill's station, and Mr. Hunter's station, at Suez, 1 double run of 8 chronometers.

10. Helroan (Dr. Döllen's station) and Great Pyramid,
1 double run of 9 chronometers, and
1 „ „ 18 „

11. Suez to Greenwich, 2 runs, 50 chronometers.

12. Greenwich to Liverpool (Bidston Observatory). 2 runs, 50 chronometers.

During these runs the chronometers were compared *inter se* twice a day.

Where the stations have been well connected by telegraphic Exchanges the chronometer runs will be chiefly used as a control on their rates.

In all these determinations, almost the whole of the time observations have been reduced in duplicate; and from many of these being made in the vertical of a circumpolar (Döllen's method) the work has been one of considerable labour, though the great accuracy obtained fully compensates for this. The telegraphical exchanges are also reduced, so that the results of the telegraphic longitudes are nearly complete; in these interchanges nearly 10,000 signals have been sent.

The 50 chronometers employed were tested for nine weeks (some longer) at the Liverpool Observatory, one week at each of the following temperatures: 85°, 70°, 55°, 70°, 85°, 70°, 55°, 70°, and 85°, before the expedition, and after the return, one week each at 55°, 70°, 85°, 95°, 85°, 70°, and 55°.

An investigation has been made from the data furnished by these trials on the temperature co-efficients; and tables, showing the correction (Thermal) for every degree Fahrenheit, between 55° and 95°, have been constructed for each instrument separately.

This investigation has been one of great labour, and has been extended to many chronometers besides those used in the expedition, from data supplied by Mr. Hartnup, from the trials at the Liverpool Observatory; one peculiarly interesting and instructive case being that of a chronometer whose daily rate in various temperatures has been recorded without interruption for ten years.

We hope that the results of these investigations, coupled

* By a "double run" is meant the chronometers being sent and returning forthwith to the same place.

with much information collected by the makers, will help to extend the knowledge of the chronometer, its errors, and their causes.

The temperature has been found from day to day during the expedition by means of an uncompensated chronometer, whose rate is affected about 6 sec. a day for 1° Fahr., and the application of these corrections is now being proceeded with.

The observations for latitude with the altazimuth, and with the transit instrument, in the prime vertical, are reduced.

The reduction of the observations on *Juno*, with the heliometer, is delayed until the meridian observations of the stars of comparison are completed, till the zone of stars observed for absolute value of the scale, and temperature co-efficient, has been remeasured, and till the extension of the division errors up to 2° distance is finished, as well as a redetermination of the errors of the screw of the reading microscope.

All these determinations are being pushed on as rapidly as possible. The reduction of the *Venus* heliometer measures is also delayed for the same purpose.

A redetermination of the screw of Airy's D.I. micrometer, used on *Venus* by Dr. Copeland, will be concluded before the reduction of those observations.

The instrument for measuring the photographs of the Transit is now almost complete, and the investigation of the errors of its scales and microscopes will be undertaken as soon as it is erected.

The photographs have been found to bear a magnifying power of 10 diameters well; and some will bear 20 with advantage.

Dun Echt, 1875, *Nov.* 12.

On the Error of the Tabular Place of Venus during the Transit of December 8, 1874. By Colonel Tennant, R.E.

(*From a Letter to E. Dunkin, Esq., Honorary Secretary.*)

I have been waiting till I should have something definite to say about the error of the place of *Venus* during the Transit, though I have long seen that there must be some mistake in Mr. Hind's estimate of the accuracy of M. Le Verrier's Tables. I have now completed the reduction of the altazimuth observations with the following result:

Correction to (R.A. ♀) −(R.A. ⊙) = +4″·47 −0″·071 dL −0·989 $d\pi$

„ (N.P.D. ♀)−(N.P.D. ⊙) = +2″·24 −0″·017 dL −2·629 $d\pi$

The longitude has been assumed as $5^h\ 11^m\ 31^s{\cdot}00$ E. which turns out to be exactly what Mr. Pogson makes from signals we

have interchanged; but, of course, the longitude of Madras must be determined by telegraph, and then there will be some correction, and I may vary the amount by a few hundredths of a second of time from small corrections which have not been included by Mr. Pogson.

If the terms for longitude and solar parallax (which, by-the-bye, has been assumed as 8″·93, log.=0·95085) be left out, then the probable error of the R.A is ± 0″·312, and of N.P.D. ± 0″·443.

Roorkee, October 14, 1875.

On an Old Drawing of the Sun. Translation from a Letter from Signor Capello, Director of the Observatory at Lisbon, to Dr. De La Rue.

I take the liberty of sending you a photographic copy of an allegorical plate representing the Sun, by Sheiner and Kircher, published at Rome in 1635.

I do not know to what work the plate belongs. I have not met with it in the *Rosa Ursina*, nor in the other works of Sheiner or Kircher.

Looking at this plate, one would be tempted to believe that the observers in question were already acquainted with the Protuberances and the Photosphere.

The clouds or fumarols all round the solar disk may very well represent the Protuberances, and the series of little tongues of fire may also very well represent the Photosphere. At any rate, it is an extraordinary coincidence, for both of them are quite recent discoveries.

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*Drawings of Mars and Jupiter, made with the 26-inch Equatoreal of the United States Naval Observatory.**

(*Communicated by Rear-Admiral C. H. Davis, U.S. N. Supt.*)

I.

These drawings were made with coloured chalk crayons on ordinary crayon paper in the following way. A circle three inches in diameter was first drawn in lead pencil on a small piece of the crayon paper, and this was secured to a small board, which was convenient to hold in the hand. The Washington mean time of beginning the drawing was (usually) noted to the

* The drawings are preserved, and may be inspected in the Library of the Society.—Ed.

nearest minute, and the drawing was begun by sketching in the most prominent lines, the details of the central parts being next filled in, and those of the extreme zones last. The time of the ending of the drawing was then noted, and a careful comparison of the completed drawings made with nature, and a few alterations made. The actual features of the drawing usually correspond to the mean of the times of beginning and ending. No account was taken of the elliptic form of the disk, as the drawings were regarded peculiarly as studies of the central parts of the disk, both as to forms and colours, though quite as much pains was taken with the extreme portions. The work was done with the full aperture, 26 inches, and usually with a positive eye-piece magnifying 400 diameters. The other and more important work of the telescope forbade the removal of the filar micrometer, and the insertion of a glass plate ruled into squares, as was originally proposed, so that the positions of the bands, &c., are merely careful eye estimates. Particular attention was paid to studies of the colours of the disk; and although the drawings are quite unsatisfactory in this respect, owing to the want of skill of the observer, and the difficulty of obtaining proper crayons, it has been attempted to supplement the drawing by verbal descriptions. Standards of colour have been sought for; one of the most satisfactory has been indicated by Prof. Cleveland Abbe, of the United States Signal Service. The horizon is frequently surrounded on the hot summer days, in the middle portions of the United States, with piles of cumulus clouds, among which (in the recesses near the bases, and occasionally on the surfaces), may be found a reddish or salmon colour, which is quite similar in tint and intensity to the normal colour of *Jupiter's* main belt during 1875. It has been noticed with some surprise that the same reddish salmon colour is the prevailing tint of *Mars*, except that this red is more glaring and strong. After many trials it was found that the best results for colour were obtained by using the *same* crayon for drawings of both *Mars* and *Jupiter*. Owing to the low altitude of *Mars*, drawings of this planet were soon abandoned, in spite of his otherwise favourable position.

II.

Description of the Photographs.

By a misapprehension the photographer has photographed not only the drawing, but a narrow space about it. In all cases the pencil border of the drawing shows in the photograph, and is the true limit. Any marks beyond this are simply portions of the crayon dust rubbed over this line in the process of drawing, except in the case of the egress of satellites, &c., which cases can be easily distinguished. The photographs show *only* the forms; the relative blackness of the various pictures is not at all kept in the different photographs.

III.

Detailed Descriptions of the Drawings of Mars.

Drawing No. 1. 1875, June 14. Observer, Holden. $11^h\ 15^m$ to 30^m; bad seeing; 400 magnifying power. I see no polar white; sketch made with power of 175; image very poor; sketch finished $11^h\ 38^m$. The border around the reddish and black parts should be a yellowish red. Some of the details put in with power 400.

Drawing No. 2. 1875, June 16. Observer, Holden. Begun $10^h\ 40^m$, finished $11^h\ 15^m$; magnifying power 400. Slight indications of polar snow, especially at south pole. The whole southern hemisphere unsatisfactorily drawn. It is full of delicate detail, hard to represent.

Drawing No. 3. 1875, June 21. Observer, Holden. Mere sketch finished $10^h\ 45^m$; magnifying power 400. *Mars* so low that it is very unsteady. I have noticed several times small *white* projections from the limb near the south pole. They are so unsteady that I cannot draw them. I should call them *round*, and brilliant white.

Drawing No. 4. 1875, June 23 (2 drawings). Observer, Holden. Magnifying power 400 (1st); from $10^h\ 15^m$ to $10^h\ 37^m$. Seeing bad at first, but suddenly becomes better. First drawing left unfinished and No. 2 begun. Second drawing begun $10^h\ 20^m$, finished $11^h\ 7^m$. Seeing much better than any other drawing of *Mars* this year.

Drawing No. 5. 1875, August 5. Observer, Holden. Magnifying power 400; begun $8^h\ 20^m$, ended $8^h\ 47^m$. Whole drawing unsatisfactory, but a few things certain. South pole quite white, north pole somewhat so. A small projection near south pole, at or about *a*; forms on the disk not well caught. Red colour satisfactory; none of the rest quite so. From *a* to *b* a long bright yellow edge to the disk; that is, inside the border.

IV.

Detailed Description of the Drawings of Jupiter.

Drawing No. 1. 1875, June 9. Observer, Holden. Magnifying power 400. Imperfect sketch, finished $9^h\ 30^m$.

Drawing No. 2. 1875, June 10. Observer, Holden. 2 imperfect sketches: No. 1. $8^h\ 20^m$ to $8^h\ 35^m$; No. 2. $8^h\ 35^m$ to $8^h\ 46^m$.

Drawing No. 3. 1875, June 16. Observer, Holden. Magnifying power 400; drawing finished at about $9^h\ 55^m$. Seeing not good, but image fairly seen at times.

Drawing No. 4. 1875, June 18. Observer, Holden. Magnifying power 400; begun $7^h\ 55^m$, finished $8^h\ 22^m$. The atmo-

sphere is hazy, but image steady. The whole planet has a yellow tinge from the haze, which is not kept in the drawing. The red is too red, and the slate colour too bright and too marked; but the cloud forms are well kept.

Drawing No. 5. 1875, June 21. Observer, Holden. Magnifying power 400; $8^h\ 0^m$ to $8^h\ 40^m$. Seeing very fine. The space A B C is too large; that is, the rest of the drawing is crowded, but most of the forms are kept. The central band is of a rose pink, banded in the strands like a rope and *covered* with a thin veil of white cloud, whose prevailing shapes are mountain like . The whole drawing is unsatisfactory, but still quite faithful.

Drawing No. 6. 1875, June 23. Observer, Holden. Magnifying power, 400. $8^h\ 3^m$ to $8^h\ 27^m$. Seeing good for first ten minutes, and then grows rapidly worse; drawing not wholly finished. The worst fault in this picture is that the outlines of the parts bordering on the *main* red belt (which is to-night entirely in the north hemisphere) are a little too *prononcés*.

Drawing No. 7. 1875, June 54. Observer, Holden. Magnifying power, 400. Begun $8^h\ 15^m$; ended $8^h\ 55^m$, *aa'* and *bb'* too far apart. Seeing not first rate. The columnar structure uniting *aa'* and *bb'* is too coarse; these little pillars are bright shining points. General Note on all. Colour of central band in all drawings of *Jupiter*. Try to get it a cross between rose pink and salmon colour.

Drawing No. 8. 1875, July 8. Observer, Holden. Magnifying power, 400. $8^h\ 15^m$ to $8^h\ 50^m$. Tint of *Jupiter* a pale yellowish-white. Tint of bands rosy pink with a dash of salmon colour; the pink of central band looks as if seen through a gauzy white cloud.

Drawing No. 9. 1875, July 13. Observer, Holden. Magnifying power, 400. Emersion of Satellite, I. $16^h\ 6^m\ 10^s$ to 30^s? by clock. Clock correction = + 16^s. Drawing begun at $8^h\ 40^m$, ended at $8^h\ 57^m$. Seeing very poor and planet yellow. The position of the shadow of the satellite is that for $8^h\ 40^m$, Whole drawing very unsatisfactory. The general aspect of the planet is not caught, and seeing is too bad to be quite sure of the individual forms. That of the oblique cloud preceding the satellite's shadow is fairly well drawn.

Drawing No. 10. 1875, July 14. Observer, Holden. Magnifying power (probably) 400. Begun at $8^h\ 0^m$; ended at $8^h\ 27^m$, on account of cloud. Drawing is not completed. The southern quarter is almost an olive green; the northern quarter approaches this tint.

Drawing No. 11. 1875, July 16. Observer, Holden. Magnifying power, 400. Begun $8^h\ 32^m$; ended $8^h\ 48^m$. Very unsteady. Planet yellow; general appearance of forms between *aa'* and *bb'* like those of June 21 or June 24.

Catalogue of Points on the Moon's Surface whose position has been recently determined by Micrometrical Measures. By E. Neison.

Those who have devoted attention to astronomical questions in connection with the Moon have long recognised the necessity of the completion of the system of measured points on the lunar surface. In especial, for the adequate mapping of the lunar surface, it is essential that the present mere skeleton of a system of measured points should be properly filled in by the determination from micrometrical measures of the position of a requisite number of new points.

Lohrmann was the first to attempt to form such a system, and from 150 good measures he ascertained the position of 21 points, though five of these, resting on fewer than five measures, were merely approximations.

It is however to Mädler that the real commencement of this work must be ascribed, as Lohrmann's results were too partial to be regarded as being properly such. From 784 measures* Mädler determined the places of 85 new points on the lunar surface, besides increasing the accuracy of seven of Lohrmann's places by additional measures, numbering in all 31. By uniting Lohrmann's measures with his own, Mädler obtained a series of 105 points whose places had been determined with some accuracy, and resting mainly on from eight to eleven measures.

Since 1832, however, nothing further has been done with a view of completing this work, though this has always been recognised as desirable. It is true Mädler subsequently made a few measures to determine the place of the north pole of the Moon, and Bessel and Wichmann ascertained the place of Mösting A: these were made, however for different and special purposes.

In its present condition, the system of measured points on the lunar surface is entirely inadequate; and, with the exception of Manilius and Mösting A, the places of the points have not been determined with sufficient accuracy for several important purposes. But though Bessel, Encke, and Mädler have urged the desirability of obtaining additional determinations, and the British Association appealed for further results, no attempt until now appears to have been made to complete the work left by Mädler in 1832.

As the subject appeared pressing, and (selenographically at least) of the highest importance, in 1873 it was determined to undertake as far as possible the extension of the present series of measured points. For this purpose, during 1874 and 1875,

* Mädler made 919 measures, but 104 were subsequently rejected as discordant, or for other reasons.

numerous measures were obtained whenever possible, employing a modified method, and using a somewhat more convenient system of reduction than Mädler's. This method was framed with a view of admitting of the introduction, at any subsequent time, of a correction for the effects of any real libration.

On the basis of these measures the following Catalogue has been founded, and rests on the results of 340 sets of measures, each consisting of five separate results. The Catalogue consists of the name of the point, the longitude and latitude found, and the number of measures these are based on. The designation of Beer and Mädler for the same, together with the place previously assigned to the point, are also added, as well as the name of the authority for this place. In the column giving the class of measures, 1st stands for points of the First Order, and 2nd for points of the Second Order, using Mädler's classification. The first are measured from the limb by the method of Encke, and the latter from one of these last, by a measure with a position micrometer. These latter are of course in a very marked degree inferior in point of accuracy to the first. In the column of authorities, L stands for Lohrmann, M for Mädler, and W for Wichmann.

The Catalogue comprises 35 points in all, and includes four whose places had previously been determined with some accuracy by Lohrmann, and four others whose position had been fixed still more satisfactorily by Mädler. Those eight points enable a comparison to be made between these new measures and those of Lohrmann and Mädler. The remaining points have been selected mainly for the purpose of fixing accurately the position of the lunar equator and first meridian, or else to fill the most important gap in the system of Beer and Mädler, or, finally, for some analogous special point, mainly directed with a view to the requirements of a new investigation into the real libration of the Moon.

The series taken in unison with the results given by Mädler in the *Der Mond*, establish with a very considerable accuracy the position of the points—Gassendi, Kepler, Landsberg, Bode, Lalande, Murchison A., and Hipparchus C. Taken together with the results obtained by Nicollet for Manilius and Wichmann for Mösting A., they will enable the exact position of the lunar equator and selenographical first meridian to be ascertained with some precision.

Catalogue of Points on the Surface of the Moon, whose Positions have been Determined from Micrometrical Measures, during 1874–1875.

Name	No. of Observations.	Position from Recent Measures. Longitude.	Latitude.	Beer and Mädler's Designation.	Class of Measures.	No. of Measures.	Position from Previous Measures. Longitude.	Latitude.	Authority.
		° ′ ″	° ′ ″				° ′ ″	° ′ ″	
Agrippa	3	10 4 17 W.	3 55 20 N.	Agrippa	1st	9	10 22 13 W.	4 4 16 N.	L.
(*a*) Archimedes A	17	7 10 47 E.	27 44 58 N.	Archimedes A	2nd	1	6 31 E.	27 56 N.	M.
(*b*) Bessarion	11	37 0 41 E.	14 58 48 N.	Bessarion ?	2nd	1	37 5 E.	14 37 N.	M.
Bessel	7	17 22 26 W.	21 54 14 N.	Bessel	2nd	1	17 37 W.	21 43 N.	M.
Bode	28	2 39 21 E.	6 37 55 N.	Bode	1st	6	2 30 48 E.	6 37 54 N.	L.
Bode A	6	1 19 40 E.	8 53 57 N.	Bode A	2nd	1	1 16 E.	8 56 N.	M.
Bode B	6	3 9 41 E.	8 42 20 N.	Bode B	2nd	1	3 0 E.	8 23 N.	M.
Bohenberger A	4	39 24 10 W.	17 3 8 S.	Bohenberger *a*		Estimated	39 10 W.	17 4 S.	M.
Brayley	5	36 25 10 E.	20 53 52 N.	Euler A	2nd	1	36 36 E.	20 46 N.	M.
Encke	7	36 35 35 E.	4 18 14 N.	Encke		Estimated	36 40 E.	3 40 N.	M.
Encke B	8	36 18 56 E.	1 57 6 N.	Encke *b*		Estimated	36 20 E.	1 30 N.	M.
Eratosthenes	7	11 41 19 E.	14 23 58 N.	Eratosthenes	1st	6	11 26 22 E.	14 26 35 N.	L.
(*c*) Gassendi	10	39 30 6 E.	17 0 48 S.	Gassendi A	1st	9	39 31 37 E.	16 55 40 S.	M.
Guerike C	8	11 43 37 E.	11 48 53 S.	Guerike C	2nd	1	11 39 E.	11 13 S.	M.

Name.	No. of Observations.	Position from Recent Measures. Longitude.				Latitude.			
		°	′	″		°	′	″	
Hipparchus C	18	8	3	34	W.	7	22	27	S.
(*d*) Hortensius	12	27	41	8	E.	6	2	8	N.
(*e*) Kepler	14	37	38	58	E.	7	57	48	N.
Lalande	17	8	47	41	E.	4	26	34	S.
Landsberg	9	26	18	49	E.	0	25	28	S.
Landsberg A	8	31	5	26	E.	0	2	20	N.
Mädler	5	29	11	58	W.	10	55	59	S.
Marius	2	49	57	5	E.	11	58	44	N.
Menelaus	11	15	31	2	W.	16	24	17	N.
Milichius	11	29	40	1	E.	10	0	15	N.
Mösting	6	5	53	2	E.	0	36	26	S.
Mösting A	24	5	13	56	E.	3	10	25	S.
Murchison A	18	1	0	4	W.	4	3	57	N.
Proclus	6	46	28	24	W.	16	12	8	N.
Ptolemaus A	10	0	58	22	E.	8	34	58	S.
Reinhold	10	22	37	26	E.	3	13	19	N.
(*f*) Rosse	8	34	19	38	W.	17	48	37	S.
Ukert	11	1	9	10	W.	7	48	24	N.
Wichmann	4	37	56	13	E.	7	41	15	S.

Beer and Mädler's Designation.	Class of Measures.	No. of Measures.	Position from Previous Measures. Longitude.				Latitude.				Authority.
			°	′	″		°	′	″		
Hipparchus *c*	2nd	1	8	18		W.	7	19		S.	M.
Hortensius	2nd	1	27	52		E.	6	56		N.	M.
Kepler	1st	11	37	42	18	E.	7	46	13	N.	M.
Lalande	1st	6	8	44	23	E.	4	20	3	S.	L.
Landsberg	1st	10	26	33	49	E.	0	29	51	S.	M.
Landsberg A	2nd	1	30	43		E.	0	5		S.	M.
Theophilus A	2nd	1	29	34		W.	10	58		S.	M.
Marius	2nd	1	50	27		E.	11	27		N.	M.
Menelaus	2nd	1	15	46		W.	16	13		N.	M.
Milichius	2nd	1	29	57		E.	10	20		N.	M.
Mösting	2nd	1	5	54		E.	0	38		S.	M.
Mösting A	1st	50	5	13	23	E.	3	10	55	S.	W.
Triesnecker A	2nd	1	1	6		W.	3	57		N.	M.
Proclus	1st	9	46	31	34	W.	16	9	8	N.	M.
Ptolemaus A	2nd	1	0	44		E.	8	56		S.	M.
Reinhold	2nd	1	22	36		E.	3	4		N.	M.
Fracastorus E	2nd	1	33	41		W.	17	27		S.	M.
Ukert	2nd	1	1	26		W.	7	33		N.	M.
Euclides *a*		Estimated	37	35		E.	7	50		S.	M.

With regard to these results, the following Notes seem desirable:

a. (Archimedes A.) There is a very considerable discrepancy between the place of this crater as given by Mädler and as found by these later measures; and this difference appears to be too large to be due merely to errors incidental to the process adopted by Mädler in making his measures of the 2nd order. In the *Der Mond* the symbol for the point measured is not given, but in the map the crater A alone answers to the description, though it is placed in only 6° 22′ E longitude, the latitude being the same. Mädler's place appears to be, however, undoubtedly wrong. From measures that have been made it would appear, in fact, that not only is the crater A placed too near Archimedes, but that this last great walled plain is too far west.

The measures on which the position of this point rest were made in two separate series, divided by a period of four months, and are:

1st	Archimedes A.	8 measures.	7° 7′ 52″ E. Long.	27° 46′ 48″ W. Lat.
2nd	Archmedes A.	9 measures.	7° 13′ 23″ E. Long.	27° 42′ 53″ W. Lat.

These results are therefore very fairly accordant, though some of the separate results exhibit peculiar differences, analogous to similar features presented in some of Mädler's series.

b. (Bessarion.) Some uncertainty attaches to the identity of this point. Mädler describes Bessarion in the *Der Mond* as a 6° bright crater, with, on its north, a light spot containing a small brighter crater in 37° 5′ E longitude and 14° 37′ N latitude, and his map agrees with this description. On the Moon, however, Bessarion under high illumination appears to occupy the centre of an elliptical bright spot, and the centre of this spot has been measured. No favourable opportunity has yet occurred to enable the exact relation of this elliptical white spot to the ringplain Bessarion to be ascertained.

c. (Gassendi). The glittering 7° bright point towards the centre of Gassendi, measured by Mädler, was considered by him to be a point about five miles north of the principal centre peak, and not to be a central elevation. This does not appear to be exact, and this 7° bright point seems to be undoubtedly the most northern central peak. It is this last that has now been measured, and no bright point exists immediately north of it.

d. (Hortensius). The place assigned by Mädler to this formation appears to be certainly nearly a degree too far north, and to be due to an error in reducing the observation that was made. None of the measures on which its position now rests gave a latitude within some half a degree of that assigned by Mädler. The point measured was the centre of the glittering spot that appears to occupy the site of Hortensius in high illuminations. According to Mädler this occupies the exact site of the crater, and this is certainly correct, for four additional measures taken

of the centre of the crater when close to the terminator give the following position:

Hortensius	4 measures	27° 45′ 22″ E. Long.	6° 0′ 46″ N. Lat.

e. (Kepler). The considerable discrepancy between the two places, though both of the first order, admits of an easy explanation. Of the eleven measures on which the position assigned by Mädler rests, three were made during the very commencement of the work; and many of the results obtained by Mädler during this period he had to reject as faulty. Now these three measures, though retained by Mädler, are discordant when compared with the other eight, as they place the latitude nearly three-quarters of a degree farther south than the rest do. These three should obviously be rejected, and then the other accordant eight measures give for the place of this point, Kepler, 8 measures, 37° 43′ 21″ E. long.; 7° 55′ 33″ N. lat. This result agrees entirely with the position derived from the later measures.

f. (Rosse). This name has been applied, as the point is very well placed for a point of the first order, and requires a special name. The Rosse of Webb has an unsuitable locality on the S.W. quadrant.

This Catalogue has not been delayed until the completion of the work, as this will occupy a considerable period; and these places being in many cases far more accurate than Mädler's, will be found very useful in selenographical work now proceeding. Moreover further work in this direction has been suspended, pending a thorough examination of the Moon's limb, the irregularities on which exert considerable influence on this work.

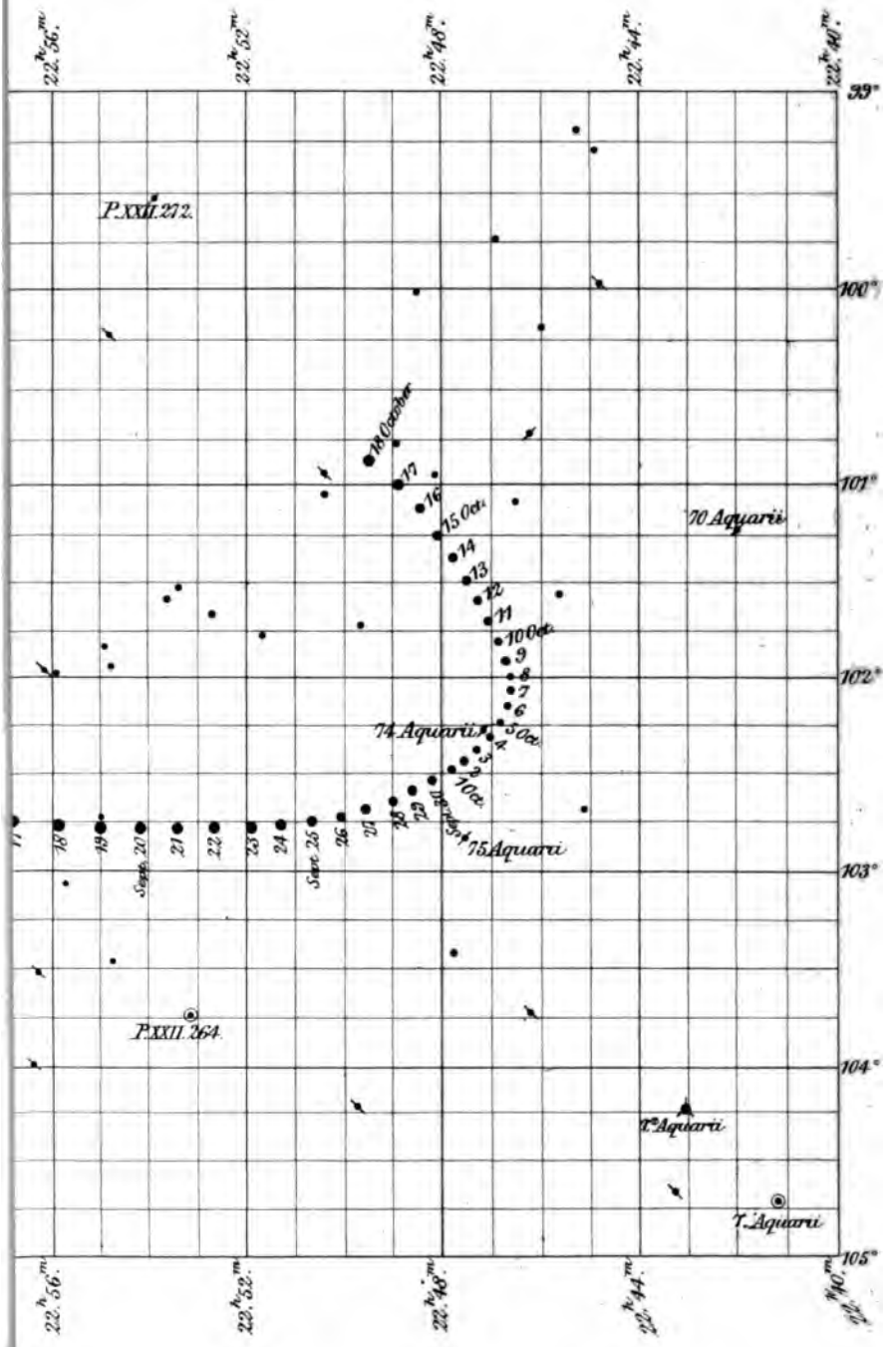
Chart of the Apparent Path of Mars, 1877, with Neighbouring Stars.

(*Communicated by the Astronomer Royal.*)

The accompanying chart has been prepared with a view of facilitating observations for the determination of the Solar parallax, the stars down to the ninth magnitude having been laid down from Bessel's "Catalogus Stellarum in Zonis Regiomontanis" (Weisse's Bessel), applying $+2^m\ 42^s$ to the R.A., and $-17'$ to the N.P.D. of each star for precession since 1825. The daily positions of *Mars* are, for Greenwich Mean Noon.

The approximate places of the stars are given in the following table:—

7.


22h 56m
22h 52m
22h 48m
22h 44m
22h 40m
99°
100°
101°
102°
103°
104°
105°
P.XXII.272.
P.XXII.264.
70 Aquarii
74 Aquarii
75 Aquarii
T. Aquarii
T. Aquarii
18 Octobr.
17
16
15 Oct.
14
13
12
11
10 Oct.
9
8
7
6
5 Oct.
4
3
2 Oct.
1 Octobr.
Sept. 20
Sept. 25

No.	Mag.	Mean R.A. 1877, Jan. 1. h	m	s	Mean N.P.D. 1877, Jan. 1. °	′
1150	9	22	55	55	101	58
1156	8		56	4	101	55
1165	8		56	18	103	32
1166	8		56	22	103	59
1184	9		57	27	102	57
1204	8		58	1	102	50
1214	9		58	36	100	14
1231	8		59	22	101	33
1232	8		59	27	101	6
1240	9		59	45	100	3
1241	7		59	50	100	15
1245	9	23	0	10	99	18
1249	8		0	30	103	23
1254	9		0	46	102	31
1258	8		0	53	99	29
1261	8		0	56	102	28
1276	9		1	53	102	16
1279	8		2	2	99	40
1292	9		2	40	101	21
7	9		2	54	99	51
9	9		2	59	103	17
12	9		3	11	102	43
14	9		3	17	102	45
20	9		3	30	101	11
27	8		3	57	103	58
36	9		4	29	99	17
42	9		4	46	99	52
49	9		5	3	101	10
56	9		5	30	99	40
57	8		5	32	102	36
69	9		6	12	101	0
72	9		6	21	103	29
73	9		6	22	103	16
76	7		6	34	100	14
79	9		6	42	103	20
84	8		7	4	99	35
85	9		7	4	100	36
92	8	23	7	16	100	59

No.	Mag.	Mean R.A. 1877, Jan. 1. h m s	Mean N.P.D. 1877, Jan. 1. ° ′
93	9	23 7 18	99 28
97	7	7 20	104 4
101	9	7 34	101 10
103	8	7 37	99 35
104	8	7 37	99 36
109	9	7 48	99 36
118	9	8 4	101 8
123	7	8 15	101 21
124	8	8 17	100 21
138	9	9 10	102 18
143	9	9 21	101 43
144	9	9 23	99 45
146	7	9 24	103 51
147	8	9 25	99 45
156	8	10 2	100 53
157	9	10 4	98 50
160	9	10 17	102 38
173	9	10 40	101 2
185	7	11 14	102 23
188	9	11 17	103 28
189	9	11 21	99 1
191	9	11 23	102 49
193	9	11 26	101 56
196	4-5	11 31	99 51
224	9	12 28	102 28
226	5	12 33	100 18
228	8	12 36	102 51
94 Aquarii	6	12 37	104 8
239	9	13 16	100 21
253	9	14 3	101 29
260	8	14 16	99 36
265	8	14 28	101 12
270	8	14 48	103 30
271	7	14 49	103 57
272	8	14 49	99 21
286	9	15 19	101 32
309	8	16 36	101 27
315	8	23 16 55	100 4

No.	Mag.	Mean R.A. 1877, Jan. 1. h m s	Mean N.P.D. 1877, Jan. 1. ° ′
317	9	23 17 2	99 34
322	8	17 23	99 8
323	7	17 24	99 8
365	9	19 24	101 50
373	8	19 55	103 38
377	9	20 14	100 43
381	9	20 22	101 43
385	9	20 31	101 37
394	7	21 2	103 36
402	7	21 41	102 8
403	8	21 44	102 53
417	9	22 13	99 12
423	9	22 30	100 47
427	7	22 40	99 57
440	9	23 17	99 21
453	9	23 53	101 8
463	9	24 30	100 50
474	8	24 54	102 52
483	9	25 25	98 51
484	9	25 28	101 33
485	8	25 28	102 38
488	9	25 34	101 41
P. xxiii–109	7	25 50	102 13
495	9	25 59	101 50
497	7	26 4	101 41
508	8	26 35	99 51
509	9	26 36	102 40
514	9	26 43	100 3
516	9	26 49	100 9
519	7	26 52	103 17
541	8	27 58	100 24
556	9	28 29	101 16
557	9	28 31	101 17
562	8	28 50	102 16
565	8	28 55	100 22
571	8	29 6	101 14
583	8	29 36	101 22
585	9	23 29 39	101 23

No.	Mag.	Mean R.A. 1877; Jan 1. h m s	Mean N.P.D. 1877, Jan. 1. ° ′
586	7	23 29 40	99 27
617	5	31 17	103 45
619	8	31 22	100 40
629	7	23 31 52	99 19

Royal Observatory, Greenwich,
1875, *Nov.* 12.

Spectroscopic Observations made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

Since the establishment of the new Physical Department, the Spectroscope has been used, as opportunity offered, for the determination of the motions of stars in the direction of the visual ray, by means of the displacement of the lines of known terrestrial elements in their spectra, the line usually selected being the bluish-green line of hydrogen, corresponding to the F line of the solar spectrum. Originally the comparison between the line of hydrogen and that in the star's spectrum was made by means of a vacuum-tube placed within the tube of the Equatoreal, and at a distance of either 2 feet or 4 feet from the slit of the spectroscope, the vacuum-tube being carefully adjusted to pass through the axis of the cone of rays from the object-glass, and at right angles to it; the observation was made with the tube parallel to the slit of the spectroscope in some cases, and at right angles to it in others. A convex cylindrical lens has sometimes been used in front of the slit, to give greater breadth to the star's spectrum, though the cylindricality of the prisms themselves has usually been found sufficient for this purpose.

On 1874, August 24, two concave lenses, placed side by side, were substituted for the single concave lens in the collimator-telescope, so that the rays which returned through the collimator to the eye of the observer (after reflection from the last prism of the train used) passed through a different concave lens from that on which the incident-pencil fell. The results obtained with this arrangement appeared to be affected by a systematic error, and in consequence of this the original plan was reverted to on 1875, March 4. Suspicion being thus thrown on the method of comparison adopted (in which a narrow strip of the object-glass was used for the rays from the vacuum-tube and the rest for the rays from the star) it was abandoned, and an actual

image of the comparison-light formed on the slit immediately above and below that of the star, by means of two comparison-prisms in connection with a collimating lens, great care being taken that the cone of rays filled the whole object-glass. This method has been used regularly since 1875, May 31, the position of the image of the comparison-light on the slit having been in every case carefully adjusted before the observation. Originally the relative displacement of the star line was measured by means of the slow-motion screw acting on the train of prisms, the line being brought up to a fixed point in the field of view; but on account of the uncertainty of this method, arising from loss of time in the action of the screw (though care was taken that the weight of the prisms always acted in the same direction), a new micrometer was applied on 1874, November 27, and has been used regularly since that date.

Besides the micrometer measures, the displacement of the star line has also been estimated in terms of the width of the comparison line of hydrogen, the width of the slit being also noted, and the displacement in wave-length inferred from micrometer measures of the width of the hydrogen line under similar conditions. The width of the slit has been varied as much as possible, in order to make these estimates independent of any bias from previous results. With a view to the elimination of systematic errors as far as possible, the dispersive power has been varied as much as circumstances would allow. For a dispersive power of two prisms, the train used consists of two half-prisms, the second of which is silvered on the back, so as to reflect the rays directly back through the collimator, where they are viewed by means of a diagonal prism placed close to and on one side of the slit. The magnifying power used in this case was 37. The dispersive powers of $1\frac{1}{2}$, $2\frac{1}{2}$, and $3\frac{1}{2}$ prisms are given by a train commencing with a half-prism, followed by one or more whole prisms, the spectrum being viewed by a second telescope, as in ordinary spectroscopes. The small telescope has a magnifying power of 19. All the prisms are compound.

Whenever practicable, the star line has been compared directly with the Hβ line, and the relative displacement estimated. Where this could not be done, the star line was bisected by the pointer (or thick cross-wires), and the Hβ line then compared directly with the pointer before the micrometer screw was touched. The observation being necessarily made in a dark field, it was sometimes very difficult to see the pointer and star line distinctly together, and some of the measures are consequently very discordant, especially where the star line is broad and nebulous, as in the case of *Altair*, the observations of which star are entitled to very little weight.

The measures since 1875, May 31, are the most reliable, the mode of comparison being apparently free from any possible systematic error, except what might arise from the lines being "winged" through fault in the surfaces of the prisms, a

defect which would affect a bright line, and an absorption or dark line, differently. If practicable, it would be desirable to compare the star line with the absorption line of hydrogen, as seen on a continuous spectrum.

Since 1875, May 31, the astigmatism produced by the prisms has been corrected by a convex cylindrical lens, placed within the collimator, and near the slit, a convex cylindrical lens being also used in front of the slit to give breadth to the star spectrum.

The concluded motions given in the following table have been inferred from the observed displacements, after correcting for the Earth's motion, resolved in the direction of the star; the method used being the same as that adopted by Mr. Huggins in his researches on stellar motions. The velocity of light is taken as 185,000 miles a second.

MOTIONS OF STARS IN THE LINE OF SIGHT, IN MILES PER SECOND.

(+ denotes recession; — approach.)

The observations prior to 1875, May 31, are not considered reliable; those between 1874, August 24, and 1875, March 3, are probably affected by large instrumental error.

Date.	Observer.	No. of Prisms.	Earth's Motion in miles per second.	Concluded Motion of Star. Measured.	Estimated.	Remarks.
				Vega.		
1874 July 17	W. C.	2	+ 2	−104	...	Not very certain. Star line very ill defined.
21	W. C.	2	+ 2	−145	−147	In each case, after bisection, the Hβ line was seen its own width on the red side of the star line.
Aug. 3	M.	2	+ 4	− 94	− 67	
11	W. C.	2	+ 5	− 27	− 62	
1875 June 25	M.	2	− 2	− 48	− 25	
26	W. C.	2	− 1	− 16	− 19	Everything in good adjustment.
July 8	M.	2	− 0	− 39	− 14	
12	M.	2	+ 1	− 47	− 66	Definition good. Direct comparison.
29	M.	1½	+ 3	− 38	− 39	Direct comparison.
31	M.	1½	+ 3	− 54	− 47	Very bright indeed. Direct comparison.
Aug. 30	M.	2½	+ 7	− 50	− 34	Sky hazy. Line only seen occasionally.
Sept. 3	M.	3½	+ 7	− 29	− 24	Line broad and nebulous, and not very distinctly seen. Indirect comparison.

						Arcturus.	
1874	Aug. 6	W. C.	2	+14	−114	− 96	Star low. Lines hard to see. Observation very uncertain. Compared with Magnesium.
						Altair.	
1874	Aug. 6	W. C.	2	+ 4	+ 76	+ 54	
	11	W. C.	2	+ 5	+ 68	+ 75	Observations fair at first; afterwards, difficult, through haze.
1875	June 26	W. C.	2	− 7	−102	− 26	Everything in good adjustment.
	July 8	M.	2	− 4	− 58	− 24	Line in star not well seen.
	12	M.	1½	− 3	+106	+ 85	Direct comparison doubtful. Star line faint, ill defined, and broad.
	29	M.	1½	+ 2	− 81	− 77	Star line very faint. Indirect comparison.
	31	M.	2½	+ 2	+ 14	+ 21	Indirect comparison.
	31	M.	1½	+ 2	− 22	...	Direct comparison showed the star line almost coincident with that of hydrogen.
	Aug. 4	M.	1½	+ 3	− 87	− 62	Direct comparison.
	30	M.	2½	+10	− 61	− 58	Indirect comparison.
						a Andromedæ.	
1874	Nov. 4	M.	2	+ 8	−125	−161	
	Dec. 7	M.	2	+15	+ 79	...	Definition bad.
1875	July 29	M.	1½	−15	− 15	− 11	Spectrum faint. Haze rising. Lines nearly coincident.
	Aug. 4	M.	1½	−14	− 7	− 17	Lines apparently very nearly coincident. Indirect comparison.
	30	M.	1½	− 9	− 29	− 36	Cloudy. Image faint and tremulous.

MOTIONS OF STARS IN THE LINE OF SIGHT, IN MILES PER SECOND.—(*continued*).

Date.	Observer.	No. of Prisms	Earth's Motion in miles per second.	Concluded Motion of Star. Measured.	Estimated.	Remarks.
				Capella.		
1874 Dec. 4	M.	2	− 2	− 72	...	
14	M.	2	+ 1	− 49	...	Star line broad. Hydrogen line not well defined.
1875 Jan. 22	M.	2	+12	−125	− 68	Star faint. Night hazy. Direct comparison.
				β Aurigæ.		
1874 Dec. 14	M.	2	− 2	− 25	− 50	Spectrum faint.
				Sirius.		
1875 Jan. 18	M.	2	+ 4	−140	−327	Wind high; frequent clouds. Star never long on slit. Width of slit doubtful.
20	M.	2	+ 5	− 96	− 59	
31	W. C.	2	+ 7	−282	−109	Star line hardly visible, and seldom seen. Observation doubtful.
Feb. 1	M.	2	+ 7	− 95	− 88	
Mar. 4	W. C.	2	+13	...	...	Star line seen distinctly on the red side of the hydrogen line.
9	W. C.	2	+13	+ 34	+ 40	Star line not well seen. Observation very uncertain.
10	M.	2	+13	+ 55	− 1	

						Procyon.	
1875	Mar. 6	M.	2	+14	− 40	− 30	Star line and hydrogen line nearly coincident.
	9	W. C.	2	+15	− 40	...	Star line and hydrogen line not seen together. Displacement doubtful.
						Castor.	
1875	Mar. 10	M.	2	+16	+ 7	...	
						Regulus.	
1875	Mar. 10	M.	2	+10	− 38	...	
	May 31	M.	2	+17	− 44	...	Image very unsteady. Star line faint at best, and often invisible. Bisection difficult and doubtful.
						γ Ursæ Majoris.	
1875	May 31	M.	2	+12	+ 62	...	
						η Ursæ Majoris.	
1875	June 11	M.	2	+10	+ 37	...	Star line very faint, and not often seen. Readings somewhat uncertain.
	25	M.	2	+10	− 65	−102	Star line scarcely visible when compared directly with Hβ.
	July 12	M.	2	+ 9	− 44	− 23	Star line very faint. Hβ line evidently *on* star line, which was much the broader, and not far from the centre. Uncertain.
						α Coronæ.	
1875	June 25	M.	2	+10	−119	− 31	Star line dark, and very broad and nebulous. The two lines were not seen together.

Motions of Stars in Miles per Second (*concluded*).

Date.	Observer.	No. of Prisms.	Earth's Motion in miles per second.	Concluded motion of Star. Measured.	Concluded motion of Star. Estimated.	Remarks.
			α Ophiuchi.			
1875 June 25	M.	2	+ 3	− 26	− 25	Faint. Lines nearly coincident. Indirect comparison.
July 12	M.	1½	+ 7	+154	+ 89	Faint. Not very well seen. Indirect comparison.
			α Cygni.			
1875 July 29	M.	1½	− 4	+ 58	+ 81	Star line somewhat faint. Indirect comparison.
31	M.	1½	− 4	− 70	− 80	Indirect comparison.
Aug. 2	M.	1½	− 4	− 53	− 48	Indirect comparison.
30	M.	1½	+ 1	− 32	− 36	Indirect comparison.
		2½	+ 1	− 21	...	Lines sensibly coincident.
			α Pegasi.			
1875 July 29	M.	1½	−12	− 10	− 14	Star line broad and dark. Lines very nearly coincident.
Aug. 4	M.	1½	−11	− 20	− 15	Indirect comparison.
30	M.	1½	− 4	− 66	− 40	Indirect comparison.

The results given are the means of the individual measures on the several nights of observation.
The initials W. C. and M. are those of Mr. Christie and Mr. Maunder respectively.

The following measures of lines in the spectra of *Aldebaran*, *δ Virginis*, and *Mars*, have been made by Mr. Maunder with the old star spectroscope, which has a single large prism of flint of 60°.

Dark Lines in Stellar Spectra.

Small Star Spectroscope.

The Wave-lengths are inferred from measurements of the principal Fraunhofer lines, made on 1875, April 7, combined with measures of the bright lines of certain elements given below.

Aldebaran.

1874, Nov. 24.

Micrometer. Rev.	Intensity.	Wave-length. Tenth-metres.	Elements.
49·227	4	5890	Sodium.
48·308	2	5840	
46·980	2	5755	Iron.
44·708	1	5575	Iron.
40·984	2	5440	Iron.
39·158	2	5340	Iron.
38·749	3	5320	Iron.
37·895	4	5280	Iron.

1874, Dec. 2.

Micrometer. Rev.	Intensity.	Wave-length. Tenth-metres.	Elements.
37·372		5170	Magnesium.
32·789		4990	Air.
50·737		5870	Sodium.

1874, Dec. 2.

Measures of Bright Lines from Spectra of Elements, for comparison, made at the same time as above.

Micrometer. Rev.	Assumed Wave-length. Tenth-metres.	Elements.
15·544	4480	Magnesium.
29·253	4861	Hydrogen H·β.
36·935	5167	Magnesium (b_4).
37·267	5183	Magnesium (b_1).
32·815	5005	Air.
50·872	5892	Sodium (D).

The assumed Wave-lengths are taken from Watts' *Index of Spectra*.
Micrometer A used throughout.

δ Virginis.

1875, April 13.

This Spectrum is crossed by seven dark bands which shade off on the red side, and have the appearance of being composed of a number of fine lines. The bands are numbered from the red.

No. of Band.	Micrometer. Rev.	Wave-length. Tenth-metres.	Remarks.
I.	...	...	Too faint to measure.
II.	...	...	Too faint to measure.
III.	27·939	5420	Sharp edge (on the violet side).
IV. 1st edge	31·690	5255	
2nd edge	32·646	5210	Very black.
V. Sharp edge	38·446	4960	Edge on the violet side.
VI. Sharp edge	44·204	4790	Edge on the violet side. Band faint.
VII.	...	...	Too faint to measure.
		Assumed Wave-length. Tenth-metres.	
H α	11·000	6562	From vacuum tube for comparison.
H ω	41·719	4861	

Micrometer B used throughout.

DARK LINES IN SPECTRUM OF MARS.

Small Star Spectroscope.

1875, July 1.

Micrometer.	Wave-length.	Elements.	Remarks.
10·263	6560	Hydrogen	C line.
11·158	6465	Calcium	
13·742	6257	Iron	
14·225	6217	Titanium	
15·052	6153	Sodium or Air.	
18·210	5940	Air	Very dark line.
18·506	5923	Air	Dark line.
18·840	5900	Sodium	D_1 line.
18·904	5895	Sodium	D_2 line.
19·782	5835		Dark line.
23·274	5625	Iron	
24·475	5560	Air	
25·715	5495	Iron or Air	
29·282	5337	Iron	
29·927	5305	Iron	

Micrometer.	Wave-length.	Elements.	Remarks.
30·610	5270	Iron	
31·484	5230	Iron	
31·945	5205	Chromium	
32·503	5183	Magnesium	b_1 line.
32·802	5170	Magnesium	b_2 line.
32·922	5165	Magnesium	b_4 line.

Micrometer B used throughout.

Image tremulous.

The part of the Spectrum, lying southwards from its centre, for one-third of the breadth of the Spectrum was much fainter than the rest. The slit was narrow, and lay north and south.

Besides observations of prominences, the following measures of the widths of some of the Fraunhofer lines have been made by Mr. Christie with the powerful spectroscope which Mr. Spottiswoode kindly lent during the adjustment of the Observatory spectroscope.

MEASURES OF THE WIDTH OF FRAUNHOFER LINES.

Taken with the Spottiswoode Spectroscope.

1875, September 16.

Line.	Measured Width. Rev.	Wave-length corresponding to 1 Rev. Tenth-metres.	Width in Wave-length. Tenth-metres.	Remarks.
C	0·167	6·38	1·065	
D_1	0·077	4·31	0·332	D_2 was to the eye broader and more nebulous than D_1
D_2	0·116	4·31	0·500	
b_1	0·057	2·91	0·166	b_1 seemed a thin line in the middle of a haze.
Haze	0·533	2·91	1·551	
b_2	0·220	2·91	0·640	
b_3	0·068	2·91	0·198	Two lines: a black line on the re side, and a faint nebulous line the blue.
b_4	0·200	2·91	0·582	
F	0·518	2·19	1·134	

Width of Slit = 0·001 inch.

Royal Observatory, Greenwich,
1875, *Nov.* 12.

Observations of the Solar Eclipse of 1875, September 28–29, made at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The circumstances of this Eclipse, like that of 1874, October 9, were not favourable for the determination of the corrections to the diameter of the Sun and Moon. On this occasion the magnitude of the Eclipse was only 0·119, the diameter of the Sun being unity. In consequence, observations were made with the Great Equatoreal, with a view only of determining the corrections to the tabular place of the Moon in R.A. and N.P.D., the corrections to the diameters being adopted, as in the reductions of the previous eclipse, from the results of the eclipse of 1870, December 21–22, which were obtained by the same observers.

Taking da = Correction to excess of Moon's R.A. over Sun's R.A.
$d\delta - d\Delta$ = „ „ „ N.P.D. „ „ N.P.D.
dS = „ Sun's semidiameter
ds = „ Moon's „

two series of measures were made, the telescope-observations being made by Mr. Christie, and the declination-microscopes read by Mr. Criswick.

(1). Differences of N.P.D. of the upper and lower cusps during about half an hour following the first contact, which show principally the effect of the correction

$$+ da, + dS, + ds.$$

(2). Differences of R.A. of right and left cusps during about forty minutes preceding the last contact, which show principally the effect of the correction

$$+ (d\delta - d\Delta), + dS, + ds.$$

Two resulting equations were formed from these differences by taking the sums of the constituent equations obtained by a comparison of the measured with the tabular quantity, as affected by the symbolical corrections for each of the two series of observations.

The adopted value of $d\,S$ being $-\,1''{\cdot}679$, and of $d\,s$ being $-\,0''{\cdot}492$,

$$da = -10''{\cdot}83 = -0^{s}{\cdot}722$$
$$d\delta - d\Delta = -\,3''{\cdot}98.$$

From 14 meridional observations of the Sun from Sep-

tember 13 to October 16, the corrections to the Sun's tabular place were found to be

$$\text{in R.A.} = -0^s.09$$
$$\text{in N.P.D.} = -1''.34.$$

Combining these corrections with the corresponding results of the Equatoreal observations, the following corrections to the Moon's tabular place are obtained:

$$\text{in R.A.} = -0^s.81$$
$$\text{in N.P.D.} = -5''.32.$$

Observations of the R.A. and N.P.D. of each cusp were also made by Mr. Downing with the Transit-circle. Treating these in a similar manner to the Equatoreal observations, but adopting $-0''.53$ for the correction to the Sun's semi-diameter determined from a long series of observations with the Transit-circle, and the correction of the Moon's semi-diameter from the results of the eclipse of 1870, December 21-22, observed with the Great Equatoreal, the following corrections are deduced:

$$da = -13''.53 = -0^s.902$$
$$d\delta - d\Delta = -5''.88.$$

Substituting these values for da and $d\delta - d\Delta$ in the original equations, in addition to those for dS and ds, the following are the resulting corrections to the tabular places of the Sun and Moon:

Correction to Tabular R.A. of Sun $= +1''.04 = +0^s.069$
" " N.P.D. " $= -0''.23.$

Correction to Tabular R.A. of Moon $= -12''.48 = -0^s.832$
" " N.P.D. " $= -6''.11.$

Fourteen photographs were taken with the photoheliograph during the eclipse.

The following table contains the observations of the beginning and ending:

Observations of the Beginning of the Eclipse.

	Instrument.	Clock or Chronometer.	Mean Solar Time. d h m s	Observer.
(*a*)	E. Equatoreal	Earnshaw	28 23 30 7·1	D.
(*b*)	Altazimuth	Graham 1	23 31 10·8	L.
(*c*)	Simms 4-in. No. 2	Brockbanks 436	23 30 13·8	A. D.
	6-in. Equatoreal	Webb 5380	23 31 39·3	C. B. N.
(*d*)	2½-in Altazimuth	Dent 2015	23 30 4·0	J. W. N.

Observations of the Ending of the Eclipse.

	Instrument.	Clock or Chronometer.	Mean Solar Time. d h m s	Observer.
(*e*)	S. E. Equatoreal	Sid. Standard	29 0 51 16·6	W. C.
(*f*)	E. Equatoreal	Earnshaw	0 51 16·7	D.
(*g*)	Altazimuth	Graham 1	0 51 21·6	L.
	Lee Equatoreal	Frodsham 3449	0 51 3·6	G. L. T.
	6-in Equatoreal	Webb 5380	0 50 56·1	C. B. N.
(*h*)	2¼-in Altazimuth	Dent 2015	0 51 2·6	J. W. N.

Notes.—(*a*) Very tremulous. Power 140. (*b*) Time recorded uncertain. (*c*) Power 76. (*d*) Probably from 10 to 20 seconds late. (*e*) Power 295. (*f*) Observed through cloud. (*g*) The observation was considered good. (*h*) The last contact may have occurred at the recorded time ± 7ˢ.

The initials of the Observers, W. C., D., L., A. D., G. L. T., C. B. N., and J. W. N., are those of Mr. Christie, Mr. Dunkin, Mr. Lynn, Mr. Downing, Captain Tupman, Lieutenant Neate, and Mr. Nichol.

Royal Observatory, Greenwich,
1875, *November* 12.

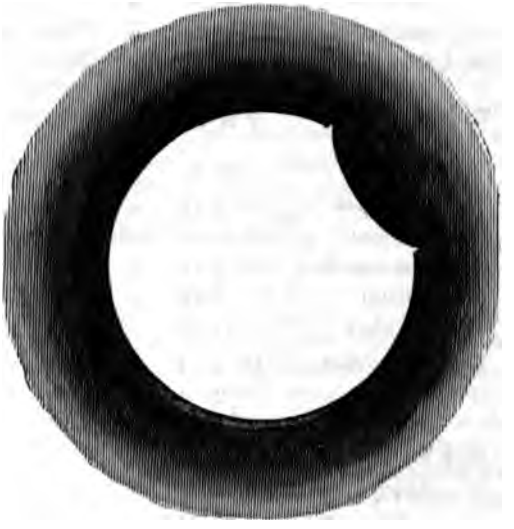
Partial Eclipse of the Sun, September 28–29, 1875, observed at Forest Lodge, Maresfield. By Capt. Wm. Noble.

I constricted the aperture of the object-glass of my Equatoreal to 2·3 inches, and observed with a power of 74 and a dark-green eye-shade. The atmospheric undulation was very great indeed. As far as I could determine, the first perceptible indentation on the limb of the Sun occurred at

$$11^h\ 57^m\ 5^s \text{ L.S.T.} = \text{Sept. } 28,\ 23^h\ 25^m\ 49^s \text{ L.M.T.}$$

The limb of the Moon was very notably smooth. Before, during, and after the time of greatest obscuration, the Sun's limb appeared to turn *very* slightly outwards—perhaps to the extent of 1″ or 1″·5—where that of the Moon cut it, giving rise to the effect of two little thorns of light projecting from it. It suggested the idea of very slight refraction of the Sun's light at the limb of the Moon. In order to eliminate anything in the shape of personal equation, and to be certain that this was an actual objective appearance, I got Mr. Noble, and Mr. J. Lister-Godlee of the Equity Bar, successively to view the eclipsed Sun, and to describe what they saw; and in each case the little

thorns of light were at once detected and mentioned by the observer. The accompanying sketch indicates this appearance very fairly.



The last contact, which I observed through massive driving cumuli, I believe to have occurred at

$13^h\ 20^m\ 26^s$ L.S.T. = Sept. 29, $0^h\ 48^m\ 56^s$ L.M.T.

Phenomena of Jupiter's Satellites, observed at Mr. E. Crossley's Observatory, Bermerside, Halifax, with the 9½ inch Cooke Refractor. By Edward Crossley, Esq., F.R.A.S., and Mr. Joseph Gledhill, F.R.A.S., F.G.S., &c.

Date. 1875.	Satellite	Phenomenon.	G.M.T. h	m	s	Observer.	Remarks.
April 13	I.	Ec. D. first beg. to fade	9	17	53	E. C. & J. G.	Good.
		half gone		18	18	„	Fair.
		disappeared		19	18	„	Good.
	I.	Oc. R. first seen	11	29	30	J. G.	May be 20 sec. in error; bad definition.
		half out		31	0	„	Pretty good.
		quite clear of disk		33	0	„	Pretty good.

Date. 1875.	Satellite.	Phenomenon.	G.M.T. h m s	Observer.	Remarks.
April 19	I.	Tr. I. first contact	13 46 54	„	May be 30 scs. in error; bad definition.
		bisection	48 24	„	Not good.
		last contact	49 54	„	Pretty good.
	I.	Sh. I. fully on disk	13 54 24	„	May be 30 scs. in error; bad definition.
April 28	I.	Tr. I. first contact	9 57 57	E. C. & J. G.	Uncertain; no definition.
		bisection	59 27	„	
		just within	10 1 27	„	
	I.	Sh. I. first seen	10 16 27	J. G.	About bisected.
	I.	Tr. E. first contact	12 6 27	„	
		bisected	8 27	„	
		just clear	11 27	„	
May 14	I.	Tr. E. first contact	10 4 4	„	Fair.
		bisected	5 4	„	Fair.
		last contact	7 34	„	Good.
	I.	Sh. E. first contact	10 42 34	„	Fair.
		bisected	44 34	„	Fair.
		last contact	46 34	„	Fair.
May 22	I.	Ec. R. first seen	9 53 49	„	Perhaps 0·5 scs. late: fair definition.
			54 28	E. C. & J. G.	Uncertain.
		full brightness	55 40	„	Probably good.
June 13	I.	Tr. I. first contact	9 33 28	J. G.	Pretty good.
		bisected	35 58	„	Not reliable.
		last contact	37 58	„	Pretty good.
	I.	Sh. I. first seen	10 40 0	„	Partly on disk: at $10^h\,43^m\,28^s$ just fully on disk, prob.
June 14	I.	Ec. R. first seen	10 5 39	„	Very bad definition.
	II.	Ec. R. first seen	49 14	„	
		full brightness	52 0	„	

Mr. Edward Crossley's Observatory,

Bermerside, Halifax.

September 29, 1875.

Occultation of Mars, observed at Windsor, N.S.W.

By John Tebbutt, Esq.

An occultation of the planet *Mars* by the Moon occurred here in full daylight on August 12, and was pretty well observed by means of the 4½-inch Equatoreal, and a power of 55. The disappearance took place at the dark limb, the first and last contact being noted at $2^h\ 58^m\ 10^s{\cdot}9$, and $2^h\ 58^m\ 40^s{\cdot}9$, local mean time, respectively. The rapid disappearance of the planet's disk was an exceedingly interesting phenomenon, its extinction taking place at a considerable distance from the Moon's illuminated disk. The line marked by the Moon's dark limb across the planet's disk was well defined, and appeared to move very rapidly till the last trace of the planet disappeared. Several small clouds were scattered over the sky during the afternoon and one of these unfortunately prevented the complete observation of the reappearance. Just as the Moon was emerging from the cloud the planet was observed as a small projection on the bright limb. I found it extremely difficult to fix the precise instant of the last contact owing to the ill-defined nature of the planet's eastern limb. This want of definition was due to the defective illumination of the limb, the planet being considerably past its opposition, and therefore gibbous. The western limb was, however, sharply defined. The last contact was noted at $4^h\ 1^m\ 24^s{\cdot}9$,; the separation was entirely complete by $4^h\ 1^m\ 27^s{\cdot}9$.

I may mention that, although the records of the Observatory for the past ten years contain a long list of lunar occultations of fixed stars, this is the only instance of an observed occultation of a planet.

Private Observatory,
Windsor, N. S. Wales,
1875, *August* 27.

Occultations of Stars by the Moon, observed at Forest Lodge, Maresfield. By Capt. Wm. Noble.

Occultation of ζ Arietis, October 16, 1875.

The star seemed to sink into the Moon's bright limb at

$22^h\ 59^m\ 48^s{\cdot}7$ L.S.T. = $9^h\ 19^m\ 53^s{\cdot}58$ L.M.T.

It re-appeared instantaneously at the dark limb at

$23^h\ 54^m\ 23^s{\cdot}7$ L.S.T. = $10^h\ 14^m\ 19^s{\cdot}64$ L.M.T.

Power 135, a positive (micrometer) eye-piece being em-

ployed on my Ross Equatoreal of 4·2 inches aperture and 61 inches focal length.

Occultation of χ Aquarii, November 8, 1875.

The star disappeared instantaneously at the Moon's dark limb at

$0^h\ 43^m\ 5^s.9$ L.S.T. = $9^h\ 32^m\ 27^s.96$ L.M.T.

The reappearance was not observed. Power 77 with a positive (micrometer) eye-piece.

Note on a Successful Attempt to support a Mercury Trough by a compact and easily removable Arrangement.

By Col. J. F. Tennant, R.E., F.R.S.

Where the level error of a Transit Instrument, or the nadir point of a transit circle, is to be found by reflection of its wires from mercury, it becomes necessary to support the mercury trough, so as to ensure freedom from tremors. I have been much troubled with the job of doing this, and having succeeded in securing a practical result, think that the mode in which I have done it will be interesting to members of the Astronomical Society.

My Transit Instrument stands on a single pier on a solid metal round base, supported by three of Colonel Strange's foot screws; there is a diametral ridge about an inch high in the middle, and four inches wide on this joining the two pillars, and above this again come the arms which raise the transit-axis, and, when turned on the centre, enable it to be readily reversed. The object end of the telescope, when the counterpoises necessary to put the two ends of the telescope in equilibrium are attached, comes within an inch of the reversing carriage, and it has not been easy to get a steady support for the mercury owing to the very confined space for it.

Messrs. Cooke and Sons supplied an iron trough which rested on the reversing carriage. This was simply intolerable, and after trying it I had to give it up at once. I have hardly ever seen the wires in it. Captain Campbell first made a wooden bridge over the reversing arrangement, placing the mercury in a hollow and supporting it on blocks of wood; but this was difficult to remove for observing, and, though the wires *were* seen, it was evident to me that an arrangement of this sort would not answer, as vibrations would be too readily propagated. I then made a trough of amalgamated copper (I believe the idea is Prof. Pritchard's), and supported it in an iron tray on a layer

of sand; the tray was carried on wooden blocks, with small pieces of sheet india-rubber to aid in deadening the vibrations by increasing the number of surfaces where there was a change of elasticity. This was used in December last, and I hoped I had conquered the difficulty, but the time was very favourable as there was (owing to the cold) no traffic at night. When the weather became warm it became manifest that I must either give up the observation by reflection, or devise some means of destroying tremor. I never hardly could get a bearable image of the wires till long after midnight, and to set half a dozen observations entailed an hour's watching.

I have now made two blocks, each a couple of inches high, consisting of six sheets of deal and an equal number of printer's blankets glued together, care being taken not to let the glue penetrate the blankets; these form piers carrying a board, supporting a large and flat dish of mercury. The result, as I anticipated, is excellent; unless carriages are passing along roads only 100 yards off, I have usually reflected wires as sharp as those seen directly. I have yet to devise some plan of avoiding glue, which will certainly yield in India, &c.; it was in the hopes of doing this that I have delayed making up the apparatus till the closing of the rainy season made action necessary.

It will be seen that the great advantage of this form of support is its extreme compactness. The use of such a suspension as that for the mercury of the Reflex Zenith Tube at Greenwich was out of the question here, both from want of space and nability to procure india-rubber, and to preserve it when got. Probably the ultimate form for use here will be a box containing coarse millboard and printer's blankets in alternate layers, but the present arrangement is more compact than anything could be made without the use of glue.

Note on Prof. Pritchard's Ephemeris of Circumpolar Stars.

By Colonel Tennant, R.E., F.R.S.

In the January number of the *Monthly Notices* (Vol. XXXV. p. 113) is a paper giving the places of 12 close circumpolar stars for the current year, in the course of which Professor Pritchard expresses a hope that the Director of the *Nautical Almanac* would take into consideration the question of publishing such Ephemerides in future. In this hope I cordially join; but I am doubtful if the stars chosen in this paper would be generally suitable.

If the ends of the great body of amateurs who have not a computing staff, and of moving astronomers, official or private, can be served as well as those of Observatories having powerful

instruments, it would, I think, be desirable. I have no doubt that other parties employed, like myself, for the late Transit of *Venus*, have felt greatly the want of circumpolar stars, and the want will be again felt in 1882. Few have had more powerful means of observing transits than myself, yet stars so small as most of those of the Oxford list would have been quite useless to me, and I should have been obliged to select some (as I have done) from such Catalogues as were available. Another reason why I think a better selection might be made is, because I doubt whether the *close* circumpolar stars are either the most convenient or most accurate for determinations of azimuth. I find that stars 10 or 12 degrees distant from the Pole are far more accurately observed, and they have the great advantage that they pass the wires much more quickly.

I think, then, that the stars selected should, if possible, not be of less than 6·5 magnitude, that they may be generally available; and that no loss of practical accuracy would result if the limit of polar distance were 15°. I do not offer my own selection, as it was made entirely from the Greenwich Catalogues, and is very defective, especially in the early hours of Right Ascension. This has partly arisen from my not using stars which had been observed very few times, but more from an apparent want of large stars in that part of the sky. It is probable, however, that a better selection may be made. If satisfactory means of determining the azimuthal correction of the Transit in each sidereal hour could be given, it would be a very great boon to many establishments where time is wanted, but where meridional observation is not a principal object.

Roorkee, September 26, 1875.

On the Aspect of the Zodiacal Light opposite the Sun.

By T. W. Backhouse.

I have lately observed a curious phenomenon respecting the Zodiacal Light which I have never heard described before; that is, a comparatively bright patch opposite the Sun. It does not appear to be generally known that the Zodiacal Light is visible at all opposite the Sun; but it is so, very commonly. But the phenomenon I now refer to is one I never noticed with such distinctness previous to September 28; on which night there was, in *Pisces*, a remarkably definite oval patch of light about 20° by 14° in diameter. Its boundary was at ϵ, ω, 21 and 29 *Piscium*, and 13 and 20 *Ceti*. Further west the Zodiacal Light faded away very suddenly; indeed at first (at $10^h\ 15^m$) I could not perceive it any further in this direction; but afterwards I could trace it, though extremely faint, to σ *Aquarii*. East of the

bright patch it faded more gradually, but at first rapidly; and was visible to near the *Pleiades*, beyond which it was rendered invisible by the Milky Way. Southwards I could, later on, trace the light, though very faint, to ι *Ceti*; and northwards to γ *Pegasi*, if not beyond. East and west of the bright patch, the Zodiacal Light was only 10° or 12° wide.

At 10.45 I perceived that the light of the bright patch was far from uniform, being rapidly concentrated, chiefly nearly along the ecliptic; the brightest part was at, or 1° north of, 44 *Piscium*. This point I find was exactly, to a degree, opposite the Sun. The phenomenon continued much the same up to $11^h\ 50^m$; and during the succeeding 10 days the point of maximum brightness gradually moved eastwards among the stars: the bright patch appearing, however, less definite.

On examining my old Notes, I find that although I never before saw so definite a patch of light opposite the Sun, still I have records of six previous instances when the light within a few degrees of the point opposite the Sun was brighter than that some distance further *p* and *f*, besides one where the greater faintness of the light *f* that point is rather doubtful. Besides these, I find 14 nights (previous to this autumn) when the light was brighter opposite the Sun than on one side of that region, the other side being obscured by the Milky Way or from some other cause. On the other hand, on October 16, 1868, I could not see the Zodiacal Light at the point opposite the Sun, though it was just perceptible a little further *f*. Also I have often seen it in that region without noticing any inequalities in it.

These discrepancies are not to be wondered at, when we consider the faintness of the phenomenon. I cannot say whether the bright patch has *really* been exceptionally definite of late; or whether it is only that my eyes have become better able to see it. The likelihood of such an occurrence is not sufficiently borne in mind by observers; who, when they see the Zodiacal Light brighter than they ever did before, are apt to conclude it has increased in brightness; while really it may only be that their eyes have become more sensitive to it. All that part of it opposite the Sun, though quite plain to my eyes, is of course very faint—so faint that it is quite doubtful whether it would be visible to a person whose eyes had not been trained to see objects of the kind. I never saw this part till 1868, though I have observed the Zodiacal Light since 1861.

Taking these circumstances into account, it seems probable that the Zodiacal Light is *always* brighter at the point of the sky opposite the Sun than at a little distance on each side of that. I have not made many observations of the actual intensity of this light; but it is probably about equal to that part of the Zodiacal Light 100° or 110° off the Sun; also to the Milky Way in the greater part of *Perseus*.

As to the cause of this phenomenon: it is highly improbable that there long protuberance of the lenticular disk (which is

generally thought to be the shape of the Zodiacal Light), away from the Earth ; and one is reminded of the anthelion on dew, but it is not likely we have in this case to deal with drops : but it is still possible that the zodiacal light is composed of particles which reflect light more readily straight towards the Sun than at other angles.

I subjoin the position of the brightest part of the light on every night on which I have seen it pretty definite. The longitude given is the distance *f* the Sun. In making nearly all these observations I was quite unaware of the actual position among the stars of the point opposite the Sun ; so that my judgment of the position of maximum brightness was quite unbiassed.

Year.	Mo.	Day.	Long. *f.* Sun. °	Lat. °	Year.	Mo.	Day.	Long. *f.* Sun. °	Lat. °
1871	11	8	185	+3	1875	10	4	180	0
1872	10	9	about 182	0		10	5	179	0
1874	10	3	„ 186	+2		10	6	near 183	0
	11	6	„ 185	+3		10	8	„ 181	+1
1875	9	28	180	0		11	5	189–180	0
	10	2	179	0		11	7	186–178	+2

Sunderland, November 9, 1875.

Observations of the Zodiacal Light at Cadiz.

By Señor A. T. Arcimis.

(*Abstract of a Paper published in the "Bulletino Meteorologico del Collegio Romano."*)

For many years I have observed this phenomenon without the assistance of any instrument; but latterly, in February and subsequent months, I have made use of the spectroscope for the analyses of this luminous manifestation. The results of my investigations are contrary to the conclusions of Prof. Wright, of Yale College, and, notwithstanding my perfect confidence in what I have observed, I did not dare to publish a work that would be received probably with some diffidence without the powerful incitement of the illustrious Director of the Observatory of Rome.

In order that the reader may appreciate the accuracy of these observations, I think it right to give an account of the place where they were taken, and the instruments employed.

The city of Cadiz forms an almost regular polygon of five kilometers of perimeter, surrounded by the sea on all sides except on the east, where a narrow neck of land runs towards the mainland.

My Observatory is established at the top of the tower of my own house, situated to the N.N.W. of the city, at a height of 131 feet above the level of the sea, and in favourable weather I can see an horizon of twelve miles radius. There being no factories in this city, the smoke of the furnaces of which might obscure the air, the thermal equilibrium is re-established between land and sea shortly after sunset; the purity of the air and the small extension of the city admitting a rapid cooling.

The aspect presented to the naked eye on the horizon of Cadiz by the Zodiacal Light is a very interesting one. Its brilliancy is superior to the Milky Way in its most conspicuous part; its colour is not homogeneous in all the extension of the spindle, nor the same every evening. It is whitish from the apex to 30° or 40°, and from that height to the horizon it becomes yellowish or reddish. The resemblance of this tint with those of the eclipsed moon gave me the idea that this cupreous tint would be produced by our atmosphere. I observed attentively the setting of the Light, and the whitish or milky portion remained unchanged.

I have repeatedly made this observation in favourable evenings, always with the same result.

The altitude of the vertex has been determined by comparisons with some of the stars, the highest being 70°.

Sometimes I have seen to the east a kind of luminousness, not belonging to the twilight, because it lasted three or four hours after sunset. Its form is that of an iron lance, and it is of a whitish colour.

In some instances the Light presented, in all its extension, a vibratory movement; but I cannot say if this was in consequence of the weariness of my sight; as in other evenings the placidity of the splendour lent a more mysterious character to the phenomenon.

Having made the description of the Light as seen by the naked eye, I proceed to record its spectrum analysis; the observations have been conducted carefully, and without any preconceived idea, and I am perplexed in considering the discordance that exists between Prof. Wright's results and my own. He has worked with accurate instruments, but his conclusions are negative; and, although my means are modest, the observations were made repeatedly, and the results are positive. I should not doubt that his conclusions are right, but at the same time I am convinced of the correctness of my own.

With a pocket spectroscope, that I directed to the central and lowest portion of the cone, I immediately detected a continuous spectrum, I can say monochromatic, similar to those exhibited by the train of some falling stars. After a short time, and familiarised with the spectrum, I detected a faint yellowish or greenish line, which I first thought to be the sodium line, but I soon convinced myself that it was more refrangible. Widening the slit, the line appeared broader, whilst it lost much of its

brilliancy. The spectrum was also visible in other parts of the sky, especially in the splendour of the east, where the greenish line appeared more vaporous. I made use of a meteor spectroscope, and detected the continuous spectrum accompanied by two luminous expansions, which were situated in the yellow and blue.

I then applied the refractor armed with a five-prisms spectroscope by Hoffmann. The greenish line was situated between *D* and *E*, and the expansion seen in the blue showed a very faint line, more refrangible than *F*. The spectrum was not very bright, but was clearly defined.

The lines observed lost much of their brilliancy in the upper parts of the cone, and at 30° or 40° they became invisible, as the continuous spectrum only remained. These observations have been repeated on several occasions.

I resolved to ascertain the positions of these lines with the utmost accuracy that my limited means permit me, and disposed the induction coil and a set of Geissler's tubes.

The oxygen gas gives a spectrum of some lines, a yellow one being extremely conspicuous. Between this and the first of a green group, is situated the yellow line of the zodiacal light. If we adopt the Kirchhoff scale—and for the line *A* the number 405, for the *C* the 694, for the *D* the 1,004, and for the *E* the 1,523—I should suppose that the number corresponding to the yellow line is the 1,480, or a little less. This estimation, it is understood, is only an approximation.

The Hoffmann spectroscope is a very good one for the more refrangible colours of the spectrum; the blue and violet are exceedingly pretty.

The position of the other line has been determined by means of a tube of coal gas. There is a group of four vaporous lines in its spectrum, and the blue line coincides with them; the number that I have assigned to it is the 2,270 of the same scale.

These observations we continued for several weeks, the Zodiacal Light being visible above the horizon of Cadiz until the middle of May, but the brilliant hues being no longer detected.

From these results, which (somewhat partially) I believe original, I think possible to infer the confirmation of the opinion of some astronomers, that the luminous atmosphere of the Sun is greater than that seen during the eclipses, its inferior part being the corona, and the limit reaching *Venus* and the Earth.

I would be very glad if some other observer, more competent than myself, would see if the lines that I have observed have any coincidence with any of the corona lines. It is possible that the line 1,480 might be the 1,474 of the *Aurora Borealis*.

Respecting the blue line, I am well convinced of its existence, but not so of its situation, nor whether it corresponds or not to the spectrum of carburetted hydrogen; but if this coincidence could be proved, remembering that the materials of comets must direct themselves to the Sun, as the great centre of attraction,

we cannot be surprised at the intimate connection which the spectroscope reveals to us between the physical nature of this star and the carbonous bodies that go to feed it.

It would lead me too far from my purpose to enter into a discussion of the before-mentioned phenomenon; others, with more right, can treat this matter with a knowledge that I do not possess.

Observations of Coggia's Comet = Comet III, 1874, made at Dunsink Observatory, Dublin.

1874	Dublin M.T. h m s	R.A. h m s	Decl. ° ′ ″	Remarks	Observer
June 11	13 41 20·0	7 2 16·63	+69 1 3·4	Very unsteady.	Brünnow.
„ 12	13 39 10·8	7 4 3·62	68 59 55·3		„
„ 13	13 34 54·9	7 7 40·17	68 56 11·8		„
„ 14	13 32 47·8	7 9 29·30	68 53 25·0		„
„ 15	13 28 35·4	7 13 9·33	68 45 41·6	Exceedingly bad atmosphere.	„
„ 16	13 24 22·8	7 16 49·16	68 34 16·2		„
„ 17	13 11 21·8	7 27 25·35	+67 26 8·5		Ball.

Dunsink, November 19, 1875.

Discovery and Observations of Eight Minor Planets (149) to (156).

Planet (149) was discovered by M. Perrotin, at the observatory of Toulouse, on September 21, the R.A. and N.P.D. at 8^h mean time of Toulouse, being respectively $23^h\ 16^m\ 8^s$ and 95° 12′. Magnitude 13.

Planet (150) was discovered by Mr. Watson, at Ann Arbor. A telegram announcing its discovery was received in Europe on October 19. Magnitude 10·11. The following early observations have been made in Europe:

1875.	h m s			Observed R.A. h m s	l.f.p.	Observed N.P.D. ° ′ ″	l.f.p.
Oct. 21	9 10 57	M.T.	Düsseldorf	0 59 2·92	...	83 14 51·2	...
25	9 8 22	„	„	0 56 18·09	...	83 35 40·4	...
26	10 46 2	„	Pola	0 55 37·60	7·311	83 41 3·8	9·792
27	13 32 10	„	Leipzig	0 54 54·53	9·422	83 46 37·3	0·807
Nov. 1	12 52 30	„	Berlin	0 52 0·73	9·378	84 9 38·0	0·818
2	9 18 25	„	„	0 51 33·87	8·863	84 13 16·4	0·810

Planet (151) was discovered by M. Palisa, at Pola, on November 1. Magnitude 12. The following are the first observations:

1875.	h m s		Observed R.A. h m s	Lf.p.	Observed N.P.D. ° ′ ″	Lf.p.
Nov. 1	13 24 25	M.T. Pola	3 2 17·04	9·096	71 39 34·9	0·604
2	10 37 26	„ Berlin	3 1 23·69	9·196	71 40 59·1	0·708

Planet (152) was discovered by M. Paul Henry, at Paris, on November 2. Magnitude 12. Its observed place at $11^h\ 0^m$ mean time of Paris was R.A. = $2^h\ 38^m\ 17^s$, and N.P.D. = 74° 35′. Motion small in polar distance.

Planet (153) was discovered by M. Palisa, at Pola, on November 2. Magnitude 12·5. Its observed place at $12^h\ 40^m$ mean time of Pola was R.A. = $3^h\ 1^m\ 28^s$ and N.P.D. = 72° 25′.

Planet (154) was discovered by M. Prosper Henry, at Paris, on the evening of November 4. Magnitude 12. The following observations of R.A. and N.P.D. were approximate, owing to unfavourable weather:

		h	R.A. h m s	N.P.D. ° ′
1875	Nov. 4	10	2 28 46	73 31
	6	8	2 26 57	73 32

Planet (155) was discovered by M. Palisa, at Pola, on November 8, and was of the 12th magnitude. The following are the original observations:—

1875.	Mean Time at Pola. h m s	Observed R.A. h m s	Lf.p.	Observed N.P.D. ° ′ ″	Lf.p.
Nov. 8	15 21 9	3 0 9·51	9·552	70 52 15·3	0·668
	16 3 6	3 0 7·58	9·599	70 52 10·3	0·696

Planet (156) was discovered also by M. Palisa, at Pola, on November 22. The telegram gives its R.A. for November 23 as $2^h\ 54^m$, and its N.P.D. 70° 30′. It had a southerly motion in declination, and its magnitude was the twelfth. E. D.

Burlington House, London,
1875, *November* 25.

Corrections to Mr. De La Rue's "Auxiliary Tables for Determining the Position of the Sun's Axis, and the Latitude and Longitude of the Earth referred to the Sun's Equator."

⊙ 90° 50′ for	diff. 4·71	read	4·70
169 40 „	50·77	„	50·27
50 „	52·69	„	52·19

Page 1, last line:—For "Heliographical Longitude of the Earth," read "Longitude of the Earth referred to the Sun's Equator."

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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PROFESSOR J. C. ADAMS, F.R.S., President, in the Chair.

Señor Augusto T. Arcimis, Cadiz;
Lieut. Cyril Corbet, R.N., Cloudesley, Bittern, Southampton;
Lieut. C. B. Neate, R.N., Royal Observatory, Greenwich;
Francis Murray Newton, Esq., Barton Grange, Taunton;
William Philip Snell, Esq., M.A., Belmont, near Havant; and
William E. Wilson, Esq., Daramona, Streete, Rathowen, Ireland;

were balloted for and duly elected Fellows of the Society.

Manila Photographs of the Transit of Venus, Dec. 8, 1874.

By the Rev. S. J. Perry, F.R.S.

I have just received from the Physical Observatory at Manila photographic copies of the solar negatives taken during the Transit of Venus last year, which, I think, may be of some interest to the members of this Society. The original negatives would, of course, be of much greater scientific value, especially if accompanied by full details respecting the methods adopted in the observations, but the copies themselves are still very suggestive.

The first was taken at Ingress near the time of bisection; the second, third, and fourth at long intervals during the transit; the fifth and sixth near internal contact at Egress; the seventh at, or extremely near to, internal contact; and the eighth, ninth, and tenth before and after, but near, bisection at Egress. Clouds prevented any more photographs being taken.

Regarding all the pictures we may remark, that the definition is excellent, and that more attention has evidently been paid in the photography to sharpness of outline in the two circles than to detail of surface. In the first, eighth, ninth, and tenth that

portion of the planet's disk which is outside the solar limb is distinctly visible, the background being decidedly brighter than the surface of *Venus*, but that part of the planet which is on the Sun is somewhat darker than the rest. This is especially noticeable in No. 9.

It seems difficult to overlook a slight increase in the intensity of the light round *Venus* when she is wholly on the Sun; this, perhaps, appears clearest in No. 4, but it is perceptible in Nos. 2, 3, 4, 5, and 6.

No. 7 is exceedingly interesting, as it was taken at the most important moment, and confirms exactly what most astronomers observed at the moment of internal contact; no deformation of the planet, but merely a slight shade where the solar cusps are about to manifest themselves. There is no decided ring of light round the planet, either when on or off the Sun, but only a slight increase of brilliancy when *Venus* is on the Sun, and a general diffused light, on which *Venus*, when off the Sun, is seen projected. It would seem, therefore, that the solar envelopes outside the photosphere produce an effect on the sensitive plate sufficiently intense to manifest by contrast the dark body of the planet. The results also seem to point to a slight actinic power in the general surface of the planet, and a still greater power in its atmosphere.

It may as yet be, perhaps, rather premature to draw any general conclusions regarding the physical results obtained during the late Transit, especially as the most valuable observations are at present under discussion and cannot be published for a considerable time. It may, however, be useful to draw attention to such individual cases as come within our reach, as the opinion of those best able to judge in these matters may thus be elicited, and our many false notions be gradually eliminated, thus leaving a clearer field for the discussion of really important details.

Stonyhurst Observatory,
1875, *December* 8.

On the Posthumous Papers of the late Professor Rigaud.

By Major-General Gibbes Rigaud.

(*Communicated by the Rev. Robert Main.*)

When, in 1839, Professor Rigaud was so unexpectedly taken from among us, there was a great feeling among astronomers that Astronomy had met with a great loss, and that in one particular line, namely, that of Scientific Biography, his loss could hardly be replaced. The Marquis of Northampton, at the Anniversary Meeting of the Royal Society, on November 30,

1839, said *inter alia*, "There was probably no other person of his age who was equally learned on all subjects connected with the history and literature of astronomy."

And his friend, Mr. Manuel Johnson, who succeeded him as Radcliffe Observer, referring to him in a printed reply to some criticisms on the work of the Observatory, spoke of him thus—"You have mentioned one, the late Mr. Rigaud, in affectionate regard for whose memory and in admiration of whose learning I yield to no one. His private virtues are remembered by many of us, and his public services will be remembered as long as Astronomy is a science cultivated amongst men."

Perhaps one of the best records of Professor Rigaud's accuracy and research was made in an article in the *Edinburgh Review* on "Sir Isaac Newton and his Contemporaries," which was published in October 1843, and which, from certain internal evidence, we should think was contributed by Professor De Morgan.

That a man cut off as Mr. Rigaud was should leave work uncompleted behind him is almost a matter of necessity; and it was known that at the time of his death he was contemplating both an edition of Pappus and also a Life of Halley, as a sequel to his *Miscellaneous Works* and *Life of Bradley*—but how far he had proceeded in his researches and lucubrations for this purpose was unknown.

Mr. Rigaud died in 1839, and for thirty-five years his papers remained carefully put away. They have, however, now been arranged, and a full table of contents completed, so that the contents of each parcel can be seen at a glance; and, that they might be accessible to all interested in him or his studies, they have been presented by his sons to the University of Oxford, to be deposited in the Library belonging to the two Savilian Professors of Astronomy and Geometry.

Among the Professor's papers were found large materials for a life of Halley, beautifully and clearly written, as all Mr. Rigaud's papers ever were, and almost ready for the press. That the life of Halley has long been a desideratum in Astronomical Biography is undeniable; but for a whole generation no one had appeared with the love of labour and spirit of research of Mr. Rigaud; it is therefore a matter for great congratulation that these inestimable papers were found, that the University of Oxford have agreed to print the work at their press, and that Professor Pritchard is in possession of all the materials collected, and has undertaken the task of editing them, with a *Life of Halley* by himself. If there were nothing but this to come out of this collection of papers the world might be content; but they are, we understand, very numerous and, what is of great importance, most legibly written, and a time will doubtless come when some one with leisure to work a mine of this sort may have infinite pleasure in finding all the Rigaud papers accessible to him.

We are enabled to give some slight sketch of these papers, which may not be without interest to some of our readers; though those who would have had most interest in looking through the work of one with whom they had been in constant correspondence, such as Bailly, Barnwell, Brewster, have all now disappeared from the scenes of their common labours.

The collection of the Rigaud papers as it now stands consists of eleven volumes of manuscript books, bound and labelled according to subjects, which he kept separate: two are entirely Halley; one Pound; another Bradley; two vols. Hearne; two Horrox, being a very careful transcript of the Greenwich MS. of the *Venus in Sole visa*, made at the time he was assisting Mr. Whatton in his researches for his *Life of Horrox*; for which, among other things, Mr. Rigaud translated the Latin Hexameters of Horrox into English verse.

There are also a good many parchment-bound books full of mathematical work and problems which he here recorded; for his careful diligence, in recording in common-place books the parts of his reading which he felt might at some future time be wanted, was perfectly marvellous. The neatness and method in which he kept his papers was remarkable. Mahogany boards and paper were cut to quarto and octavo sizes, and each paper when completed was sewn together, and when bundles had attained to a sufficient size a new one was commenced. The consequence is that all his work is beautifully preserved and legibly transcribed. It would be impossible for us to give a table of contents of all these bundles, as, in addition to all the books, there are twenty-four bundles, each with its table of contents; but some idea of the extent of these labours may be obtained from the following figures. Of the bundles of quarto size in mahogany boards there are five, and in these there are nearly sixty different papers. In the twelve bundles of octavo size in mahogany boards there are over 200 separate papers, and amongst them a list of all the papers which have been printed, and where his various contributions to the scientific literature of the day are to be found.

There were in an old box many bundles of old letters which have been carefully arranged in guard-books. These have all been arranged alphabetically, according to the names of the writers, and the guard-books lettered and a table of contents made to each, so that reference is easy; and of these letters there are 487.

There is also a guard-book containing an interesting series of 64 autograph letters, written by the most famous men of science of the last century to Mr. Magellan, as his name is always spelt, though the name should properly be written "Jean Hyacinthe de Magalhaens." There is a sketch of his life in the *Nouvelle Biographie Générale*, vols. xxxi.–11, which tells us that he was a Portuguese, born at Lisbon in 1723. He was originally an ecclesiastic, but being fonder of Natural Phi-

losophy than anything else, he came to England in 1764, and died at Islington in 1790. He had various artists under his superintendence, and produced the best instruments of the day. He was made F.R.S. in 1774, and was a member of the Academies of Science of Paris, Madrid, and St. Petersburg.

How this collection of letters passed into the hands of Professor Rigaud there is nothing to inform us; but there they are—long autograph letters on science and scientific instruments, in the autograph writing of such men as Kœstner, Achard, Anisson, Barthélemy, Benyouski, Bernouilli, Boscovich, Cassini, Espinoza, Euler, Fonseca, Gavallon, W. Herschel, Lalande, Landriani, Messier, Turgot, Volta, and many more.

But we think we have now said enough to show that a collection of papers which may be very valuable have been opened, as it were, to any one to whom they are of interest; and we think it would be well if many collections of papers left by men of science were deposited in libraries, instead of being retained in families.

Corrected Mean Solar Times of the Beginning and Ending of the Solar Eclipse of 1875, September 28–29, as observed at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The mean solar times of the beginning and ending of the Solar Eclipse as observed at the Royal Observatory, inserted on pages 39 and 40 of the *Monthly Notices* for November, should be diminished each by four minutes, owing to a constant error having been made inadvertently in the conversion of the observed sidereal times into mean solar times. It is considered, therefore, advisable to reprint the corrected resulting mean solar times of the beginning and ending of the Eclipse, to be substituted for those on pages 39 and 40.

Observations of the Beginning of the Eclipse.

	Instrument.	Clock or Chronometer.	Mean Solar Time. d h m s	Observer.
(*a*)	E. Equatoreal	Earnshaw	28 23 26 7·1	D.
(*b*)	Altazimuth	Graham 1	23 27 10·8	L.
(*c*)	Simms 4-in. No. 2	Brockbanks 436	23 26 13·8	A. D.
	6-in. Equatoreal	Webb 53	23 27 39·3	C. B. N.
(*d*)	2¼-in. Altazimuth	Dent 2015	23 26 4·0	J. W. N.

Observations of the Ending of the Eclipse.

	Instrument.	Clock or Chronometer.	Mean Solar Time. d h m s	Observer.
(*e*)	S. E. Equatoreal	Sid. Standard	29 0 47 16·6	W. C.
(*f*)	E. Equatoreal	Earnshaw	0 47 16·7	D.
(*g*)	Altazimuth	Graham 1	0 47 21·6	L.
	Lee Equatoreal	Frodsham 3449	0 47 3·6	G. L. T.
	6-in Equatoreal	Webb 5380	0 46 56·1	C. B. N.
(*h*)	2¼-in Altazimuth	Dent 2015	0 47 2·6	J. W. N.

Notes.—(*a*) Very tremulous. Power 140. (*b*) Time recorded uncertain. (*c*) Power 76. (*d*) Probably from 10 to 20 seconds late. (*e*) Power 295. (*f*) Observed through cloud. (*g*) The observation was considered good. (*h*) The last contact may have occurred at the recorded time ± 7ˢ.

The initials of the Observers, W. C., D., L., A. D., G. L. T., C. B. N., and J. W. N., are those of Mr. Christie, Mr. Dunkin, Mr. Lynn, Mr. Downing, Captain Tupman, Lieutenant Neate, and Mr. Nichol.

Royal Observatory, Greenwich,
1875, *December* 16.

Corrected Observations of Coggia's Comet=Comet III., 1874, *made at Dunsink Observatory, Dublin.*

In the observations printed at p. 51 the days are given incorrectly,* the observations should be as follow :—

1874 June	Dublin M.T. h m s	R.A. h m s	Decl. ° ′ ″	Remarks.	Observer.
11	13 41 20·0	7 2 16·63	+69 1 3·4	Very unsteady	Brünnow
12	13 39 10·8	7 4 3·62	68 59 55·3	Very bad atmosphere	,,
14	13 34 54·9	7 7 40·17	68 56 11·8		,,
15	13 32 47·8	7 9 29·30	68 53 25·0		,,
17	13 28 35·4	7 13 9·33	68 45 41·6	Exceedingly bad atmos.	,,
19	13 24 22·8	7 16 49·16	68 34 16·2		,,
25	13 11 21·8	7 27 25·35	+67 26 8·5		Ball

* The error was in the original MS.—[Ed.]

Ephemeris for determining the Positions of the Satellites of Uranus, 1876. By Mr. A. Marth.

0h G.M.T.	Ariel.		Umbriel.		Titania.		Oberon.	
	ω	diff.	ω	diff.	ω	diff.	ω	diff.
1876.	°	°	°	°	°	°	°	°
Jan. 1	261·63		290·79		91·95		258·99	
		714·19		434·33		206·74		133·68
6	255·82		5·12		298·69		32·67	
		·18		·33		·73		·67
11	250·00		79·45		145·42		166·34	
		·17		·33		·73		·67
16	244·17		153·78		352·15		300·01	
		·17		·32		·73		·66
21	238·34		228·10		198·88		73·67	
		·16		·32		·72		·66
26	232·50		302·42		45·60		207·33	
		·15		·31		·72		·66
31	226·65		16·73		252·32		340·99	
		·14		·31		·72		·66
Feb. 5	220·79		91·04		99·04		114·65	
		·14		·30		·72		·66
10	214·93		165·34		305·76		248·31	
		·13		·30		·72		·66
15	209·06		239·64		152·48		21·97	
		·13		·30		·71		·65
20	203·19		313·94		359·19		155·62	
		·12		·30		·71		·65
25	197·31		28·24		205·90		289·27	
		·12		·29		·71		·66
Mar. 1	191·43		102·53		52·61		62·93	
		·11		·29		·71		·66
6	185·54		176·82		259·32		196·59	
		·11		·29		·72		·66
11	179·65		251·11		106·04		330·25	
		·11		·29		·72		·66
16	173·76		325·40		312·76		103·91	
		·10		·29		·72		·66
21	167·86		39·69		159·48		237·57	
		·11		·29		·72		·67
26	161·97		113·98		6·20		11·24	
		·11		·30		·72		·67
31	156·08		188·28		212·92		144·91	
		·10		·30		·73		·67
Apr. 5	150·18		262·58		59·65		278·58	
		·11		·30		·73		·68
10	144·29		336·88		266·38		52·26	
		·11		·30		·73		·68
15	138·40		51·18		113·11		185·94	
		·11		·30		·74		·68
20	132·51		125·48		319·85		319·62	
		·11		·31		·74		·69
25	126·62		199·79		166·59		93·31	
		714·12		434·31		206·74		133·69
30	120·74		274·10		13·33		227·00	

	log b	p_o °	Ariel. log a	Umbriel. log a	Titania. log a	Oberon. log a
Jan. 1	9·6425 n	9·20	1·1762	1·3202	1·5351	1·6613
6	·6450	9·14	·1774	·3214	·5363	·6626
11	·6477	9·08	·1786	·3225	·5375	·6637
16	·6505	9·01	·1795	·3235	·5384	·6646
21	·6535	8·94	·1803	·3243	·5392	·6654
26	·6566	8·86	·1809	·3248	·5398	·6660
31	·6597	8·79	·1813	·3252	·5402	·6664
Feb. 5	·6629	8·71	·1815	·3255	·5404	·6666
10	·6660	8·63	·1815	·3255	·5404	·6666
15	·6691	8·55	·1813	·3253	·5402	·6664
20	·6721	8·47	·1809	·3249	·5398	·6660
25	·6750	8·40	·1804	·3243	·5393	·6655
Mar. 1	·6778	8·33	·1796	·3236	·5385	·6647
6	·6804	8·26	·1787	·3227	·5376	·6638
11	·6828	8·19	·1776	·3216	·5365	·6627
16	·6850	8·13	·1764	·3204	·5353	·6615
21	·6869	8·08	·1750	·3190	·5339	·6601
26	·6885	8·03	·1735	·3175	·5324	·6586
31	·6900	7·99	·1719	·3159	·5308	·6570
Apr. 5	·6912	7·96	·1702	·3142	·5291	·6553
10	·6921	7·94	·1684	·3124	·5273	·6535
15	·6927	7·92	·1665	·3105	·5254	·6516
20	·6929	7·92	·1646	·3086	·5235	·6497
25	·6928	7·92	·1627	·3067	·5216	·6478
30	9·6926 n	7·93	1·1607	1·3047	1·5196	1·6458

The values of ω, log b, p_o, and log a are to be interpolated for the times for which the positions of the satellites are wanted. The angles of position p and distances s are then found by means of the equations—

$$\frac{s}{a} \sin (p - p_o) = b \sin \omega,$$

$$\frac{s}{a} \cos (p - p_o) = \cos \omega.$$

The factor b (the sine of the Earth's latitude above the plane of the orbits) being at present negative, the angles of position decrease with increasing values of ω (the satellites' longitudes in their orbits reckoned from the points of their greatest northern elongations, p_o denoting the angle of position of the major axes a of the apparent orbits).

In case polar-coordinates p and s of the satellites are directly observed, these, or equivalent formulæ, or the kindred ones given in *Astron. Nachrichten*, No. 1040, will be found preferable to those adopted by von Asten and Newcomb, not only on account of their greater simplicity, but still more on account of the far greater facility and directness which they afford for computing the differential coefficients in the equations of condition for correcting the assumed elements.

Drawing of the Ring Nebula in Lyra (R.A. $18^h\ 48^m\ 20^s$: N.P.D. $57°\ 8'\ 57''$ [1860·0]). By Edward S. Holden, Prof. Math. U.S. Navy.

(*Communicated by Rear-Admiral C. H. Davis, U.S. Navy, Superintendent U.S. Naval Observatory.*)

The original drawing in pastel (of which a photograph on the same scale is sent herewith—viz. 1 inch = 20″) was constructed from the following measurements taken with the 26-inch Equatoreal of the Naval Observatory, with a magnifying power of about 400 diameters:

1874, June 13. Major axis = 77″·3; minor axis = 58″·0. Observer, Newcomb. N.B. The distances are only for the brighter portions.

1874, Aug. 10. Rough sketch of the nebula and surrounding stars. S. W. Burnham and Holden.

1875, July 7. Angles of position of four lines from bright star A (brightest in a field of 6′) tangent to the outer and inner ovals of the luminous ring.

$AB_3 = 239°$; B_3 on South side of external oval.

$AB_4 = 248°$; B_4 on South side of interior oval.

$AB_2 = 289°$; B_2 on North side of interior oval.

$AB_1 = 303°$; B_1 on North side of exterior oval.

Differences of Right Ascension between star A and tangents to the *preceding* and *following* sides of both interior and exterior ovals, the differences being measured with the micrometer:

A and $n_1 = 22''·58$; n_1 on *following* edge of exterior oval: (n_1 is not the extreme point, but it is where the nebulosity begins to be definite.)

A and $n_2 = 36''·31$; n_2 on *following* edge of interior oval (in this again there is well-marked nebulosity *preceding* n_2, that is, inside the interior oval).

A and $n_3 = 82''·27$; n_3 on *preceding* edge of interior oval.

A and $n_4 = 102''·96$; n_4 on *preceding* edge of exterior oval.

A and $n'_4 = 105''·25$; n'_4 on extreme limit of *preceding* nebulosity.

Observer, Holden.

1875, Oct. 24. Position-angle major axis, 63°·6; major axis, 88″·7 (not to the extreme limit); minor axis = 60″·1 (extreme). Sketch made of nebula: bright patches seen, and also star inside the ring. Observer, Holden.

1875, Oct. 25. Angle of position and distance of estimated centre of ring from star A, $p = 268°{\cdot}2$; $s = 61''{\cdot}6$.

$AB_2 = 241°$
$AB_1 = 298°$ } B_1 and B_2 as on July 7, 1875.

Observer, Holden.

Pencil sketch made, and from all the measures and sketches a pastel drawing made on a scale of 1 inch to 20″. Lassell's and Winlock's drawings compared with the heavens, Oct. 24 and 25.

1875, Oct. 31. Position of major axis = 63°·1; of minor axis, 156°·8.

It is not easy to decide on exact position of minor axis, and the readings are somewhat uncertain. North end of minor axis again seen with several bright points near it. Two bright patches seen. Observer, Holden.

1875, Nov. 2. Position of major axis, 65°·5; length, 89″·5: position of minor axis, 155°·8; length, 66″·5. Observer, Hall.

1875, Nov. 6. Position of star A from estimated centre of nebula, 85°·6; distance, 61″·9. Observer, Hall.

The drawing represents tolerably well the aspect of this nebula as seen at Washington under average circumstances. The bright patches in the border and the star in the interior are only to be seen in moments of superior definition, but no doubt is entertained as to their existence. The photograph should be held at a distance of about two feet from the eye, in order to represent the apparent size of the nebula as seen in the telescope with a magnifying power of 400 diameters; and at this distance the relative brightness of the stars and the bright patches is properly kept. In the photograph there are one or two bright points in the nebula beside the central star: these are imperfections. The general aspect is, however, better caught at a distance of about ten to fifteen feet, the picture being shaded from direct illumination.

The only published figures of this nebula of which I have any knowledge are:

I. Herschel's, in *Phil. Trans.*, 1833, plate x. fig. 29.

II. Rosse's, in *Phil. Trans.*, 1844, plate xix. fig. 29.

III. D'Arrest's, in *Description of the Copenhagen Equatoreal*, 1861, plate ii. fig. 5; and a good sketch in *Sid. Neb. Obs. Hav.*, p. 334.

IV. Lassell's, privately distributed, and dated Sept. 19, 1860.

V. Winlock and Trouvelot's, in *Astronomical Engravings from Harvard College Observatory*, plate xxxiv.

Beside these, there are several rough sketches of Schroeter's

and Harding's in *Beyträge zu den neuesten astronomischen Entdeckungen*, vol. i. plate vi. fig. 27, and vol. iii. plate ii. figs. 5, 6, 7, and 8.

In these Schrœter chronicles the discovery of a small star very close to the ring, and following it exactly in the prolongation of its axis major (according to his first figure), and also the finding of certain bright patches in the ring itself. Schrœter's star does not exist, unless indeed it be the star A of our observations, as D'Arrest supposes (*Sid. Neb. Obs. Hav.*, p. 334). Schrœter's first figure (vol. i.) places the small star very close to the nebulosity, and his description distinctly says, "dicht unten am Rande entdeckte ich einen ausserordentlich kleinen dunkeln kaum erkennbaren Stern." This is certainly not a description of star A, even with Schrœter's telescopic means. His later figures (vol. iii.) probably show our star A. If they do, it is variable, according to Schrœter's evidence given below; if they do not, his star has no existence at present, as it has been specially looked for.

Herschel's drawing (I.) is of very small dimensions and of no detail.

Lord Rosse's (II.) is very *suggestive* of the present appearance, though by no means a representation of the object as it is seen in the 26-inch refractor.

The wisps of nebulosity, extending outward in all directions, are not seen in the latter telescope, and it is a little curious that that end of the minor axis which Lord Rosse has represented as the best terminated, viz. the *south* end, is precisely that one which to-day, and with the Washington telescope, is least so. The difference between the two ends is here not very marked, but still the north end is sharper and brighter as it is described by D'Arrest, *op. cit.* Lassell's drawing (IV.) represents the general aspect of the nebula better than any other. Some of the details which are to be found in Winlock's (V.) are lacking, as, for example, the great diminution of light at the ends of the major axis; but the star in the interior of the ring is shown, and the elliptical shape of the nebula finely given. Winlock's and Trouvelot's (V.) is on a large scale, and is, in general, very similar to the object in the heavens, but I find the three bright spots or patches far too bright to represent their present appearance in the Washington telescope. The *following* end of the major axis appears to be too sharply terminated; the *preceding* end, however, is in excellent agreement with the nebula. D'Arrest's drawing (III.) is not at present accessible to me.

In Lord Rosse's figure, the interior of the ring is represented to be streaked in bands parallel to the major axis, and this appearance has been noted also by Professor C. Abbe with the Cincinnati Equatoreal (12 inches aperture). This does not represent the appearance as seen at Washington, but it suggests it strongly. This appearance it is not attempted to show in my drawing, but it may best be described as a tendency in the light of the interior

oval to an arrangement in streaks parallel to the major axis, and seen principally in the *preceding* half of the ring, and only under the best conditions.

The first detailed notice of bright patches in the ring itself is by Schrœter, in the work previously quoted, vol. iii. p. 164, *et seq.* and plate ii. figs. 5-8.

1797, April 16. Harding saw a bright patch (β), and he gives a rough sketch, from which I deduce the angle of position of the patch to be about 96°, and the distance from the centre about $\frac{7}{15}$ths of the diameter. (These figures are quite rough, necessarily.) The small star a (so-called by Schrœter) was seen following the nebula.

1797, Nov. 12. The star a was at once plainly seen, while of the spot β of April 16 there was not the least trace. It was for the second time remarked that the interior of the ring is filled with faint nebulosity.

1797, Nov. 19. The star a was again seen. Two sketches were made, one by Harding, and one by Schrœter, which agreed in certifying to the existence of two bright spots a and b.

a : Pos.-Ang. = 339° Dist. = $\frac{6}{15}$ths of diameter.

b : „ = 17° „ = $\frac{5}{15}$ths of diameter.

Their light was *notably* brighter than that of the rest of the nebula, and somewhat twinkling at times. The *preceding* and *following* sides of the nebula were then observed to be, as they are now, somewhat fainter than the rest.

1798, Oct. 27. The *preceding* or *western* side of the ring was seen much darker than the rest, so that the ring looked divided or broken at this point; but on the *following* side this was not the case, as on Nov. 19, 1797.

Again, both the bright spots a and b of that date had disappeared; and in a position-angle of 13°, distance about $\frac{6}{15}$ths, a bright spot c was noticed. This could not be the spot b of Nov. 19, since it was much nearer the edge of the ring.

1798, Dec. 20. The interior of the ring was bright greyish like the sky illuminated by moonlight, and the *western* (*preceding*) and outer portion of the ring itself was not half so bright as the rest of the ring, and as its following border, which, on the 19th of November 1797 had been found equally dark. No bright patches were seen in any part of the ring itself. The star a, which had been seen with difficulty on dark nights, was now plainly visible to both observers in bright moonlight.

Sir William Herschel has a few remarks upon this nebula in Bode's *Jahrbuch* 1788, p. 242. He speaks of it as apparently a ring of stars with a regular and concentric dark spot or space in the midst. "Er ist von ovaler Figur, seine kleine Axe verhalt sich zur grössern wie 83: 100. . . . Das Licht desselben ist von der auflösbaren Gattung und an der nordl. Seite kann man 3 sehr schwache Sterne erkennen, sowie einen oder zwei am

südlichen Theil. Die Ende der längern Axe scheinen weniger glänzend und nicht so deutlich abgeschnitten als die übrige. . . . *siehe* Fig. 9" [Fig. 9 is a simple sketch of no detail]. Von Hahn in the *Jahrbuch* for 1803, p. 106, has some further observations with a 20-foot reflector. "Ich finde in dem berühmten Sternring . . merkliche Veränderungen. Vor einigen Jahren war das innre Ring so klar, dass ich . . . in dessen Mitte ein teleskopisches Sternchen unterscheiden konnte. Jetzt zeigen sich . . . . schwache feine Wolken und der kleine Stern ist gar nicht sichtbar. Eine Veränderung ist sicher vorgefallen. Es kann aber auch sein, dass der Ring sein Stelle verändert hat, und nur auf dem unendlich viel weiter als der Ring entfernten Himmelsgrunde, der durchsichtige Ring anders erscheint."

From Sir John Herschel's "Observations of Nebulæ, &c.," in *Phil. Trans.* 1833, p. 462, I extract a few notes regarding this nebula: "Position of longer axis of annulus 57°·0 by micrometer . . . . diameter in R.A. $5^s{\cdot}375$ by a mean of four careful observations. The Star following it is 11^m. It follows the centre $4^s{\cdot}31$, and its position from centre is 96°·4 by micrometer. The nebula has a mottled look. [N.B. This mottled look, however, is something quite different from the appearance called resolvable.]"

D'Arrest speaks of it as follows in his *Sid. Neb. Obs. Hav.*, p. 334: "Adspectu floccosa — * 14^m (non 11^m) seq. in parallelo, * 14^m in seq. centrum accurate in parallelo $4^s{\cdot}67$. Margo borealis australi certe lucidior: in ipsa neb. 2 vel 3 fixæ subtilissimæ conspiciuntur. . . . . In limbo boreali eoque certe lucidiore duæ stellulæ satis distincte affulgent; nulla vero intus in annulo." Angul. posit. axis majoris = 58°43′. Axis major = 58°·1; axis minor = 59″·9.

Secchi (*Ast. Nach.* bd. 43, col. 160) saw, "très bien dans l'intérieur une très petite étoile un peu au-dessous (apparent) (that is, north) de son centre."

Auwers in *Ast. Nach.* bd. 58, col. 375, has the following observations (1862): "Grosse Axe des äussern Ringrandes = 75″·0 in Pos. 70°·0 Klein = 61″·5 (2 Tage). . . . Stern $11^m{\cdot}6$ $d = 61''{\cdot}1$, $p = 87°{\cdot}1$ (2 Tage): daraus folge $\Delta\alpha = 4^s\,84''$."

Dr. H. Schultz, in his recently published "Observations of 500 Nebulæ" (Upsala, 1874), has the following notes on this nebula:—

"1865, August 12. Nebula bluish and strongly granulate; north part brighter. Position of the major axis 57°·9; minor axis, 148°·9. . . .

"1865, August 13. The north part of the ring brightest; strongly granulate, with several not very faint stars seen by momentary glimpses: 2 or 3 stars in the *north-preceding* part and 2 in the *south-following* part of the ring distinctly seen; at the interior margin of the ring 2 stars visible in the *south-preceding*, and one in the *south-following* part. Hahn's star a little *north-preceding* the geometrical

centre, momentarily visible; dull and planetary. All these stars only so momentarily seen that to adjust the micrometer wire upon them was quite impossible. The *north-following* part of the ring very diffuse with nebulous radiations in the direction of the longer axis, which seem momentarily almost to destroy the annular form. The central vacuity not inconsiderably nebulous. . . . .

"1867, August 6. Hahn's central star distinctly seen without effort . . . the *north-following* end only momentarily well defined.

"1870, August 8. . . . Twinkling stellar points at the *north* outer margin, which is best defined." . . .

Lamont's observations of 1838–9, with a sketch, are given in *Annalen d. k. Stw. bei München*, bd. xvii.

My own notes on the bright patches are as follows. They refer specially to 1875, October 24–25:—

"Minor axis more sharply terminated on *north* side: near *north* end of minor axis is a bright patch. The star inside the ring is seen occasionally: it is very near the *south-preceding* corner of a square formed by three stars outside (which are Lassell's Nos. 1, 8, and 5 or 6) and itself. The whole of the interior glistening in points. At the *south* end of the minor axis filaments of nebulosity extend 15″ to 30″ off. These are very faint. The *following* end of major axis is better terminated than the *preceding*. Two brighter spots are seen in the *north-preceding* and *south-following* parts of the ring, and possibly a third in *south-preceding* part. At both ends of the minor axis are several which cannot be located exactly."

With regard to the identity of the star 14^m = Lassell No. 1 with Schrœter's star *a*, I find from Schrœter's first drawing that its distance from the *following* end of the major axis was not more than 4″ or 5″. His subsequent drawings certainly represent our star 14^m; and he refers to this 14^m as if it were the one first seen by himself and Harding on 1786, November 13.

The question is of no great importance, except as to the existence of a small star so close to the ring. As I have said, this star has been looked for, and at present does not exist.

I add a Table containing measures of this nebula, for convenience of reference:—

Date.	Angle of Position.	Distance.	Authority.
	Major Axis.		
	°		
1825–33	57·0	5″·375 (diam. in R.A.)	Herschel.
1837–9	66 22′ (mean of two varying 8°)	68″·4 (Major Axis, m.m.)*	Lamont.
1860	...	89″ („ „ „)	Lassell.
1863	58 43′	78″·1 („ „ „)	D'Arrest.

* In the table, m. stands for *measures*, and m.m. for *micrometer measures*.

Date.	Angle of Position.	Distance.	Authority.
1863	58·43′	5″·66 (diam. in R.A.)	D'Arrest.
	...	5″·30 („ „)	„
1863	70·0 (query 60°·0 ??)	75″·0 (Major Axis, heliometer)	Auwers.
1865-6	57·9	59″·7 (diam. in R.A.)	Schultz.
1874	...	77″·3 (Maj. Axis, not extreme, m.m.)	Newcomb.
1875	63·6	80″·4 (diam. in R.A., m.m.)	Holden.
„	63·1	88″·7 (Major Axis, m.m.)	„
„	65·5	89″·5 („ „ „)	Hall.

Minor Axis.

1860	...	68″ (Minor Axis, m.m.)	Lassell.
1837-9	...	55″·4 („ „ „)	Lamont.
1863	...	59″·9 („ „ „)	D'Arrest.
„	...	61″·5 („ „ heliometer)	Auwers.
1865-6	148·9	58″·1 (diam. in δ, m.m.)	Schultz.
„	...	58″·8 („ „ „)	„
„	...	56″·5 („ „ „)	„
„	...	56″·1 („ „ „)	„
1874	...	58″·0 (Minor Axis, m.m.)	Newcomb.
1875	156·8	60″·1 („ „ „)	Holden.
„	155·8	66″·5 („ „ „)	Hall.

Star 14^m = *Lassell No.* 1.

1825-33	96·4	ΔR.A. = 4ˢ·31	Herschel.
1837-9	88 22′	... ...	Lamont.
1863	″ in seq. centrum accurate in	ΔR.A. = 5ˢ·47	D'Arrest.
„	parallelo .·. 90°	ΔR.A. = 4ˢ·67	„
„	87°·1	61″·1 (dist., heliometer)	Auwers.
„	...	ΔR.A. = 4ˢ·84 (from above means)	„
1865-6	86·8 (computed from m. of Δδ)	ΔR.A. = 5ˢ·22	Schultz.
„	...	ΔR.A. = 4ˢ·86	„
1875	...	ΔR.A. = 62″·8 (m.m.)	Holden.
„	...	= 4ˢ·99 (computed from above)	„
	88·2	61″·6 (distance m.m.)	„
„	85·6	61″·9 („ „)	Hall.

In this table I remark the following differences:—

1st, Position of major axis:

Holden—Herschel	=	+6·4°	1825-33
„ —Lamont	=	−3·0	1837-9
„ —D'Arrest	=	+4·7	1863
„ —Auwers	=	−6·6	1863 (query +3°·4??)
„ —Schultz	=	+5·5	1865-6
„ —Hall	=	−1·1	1875

2nd, Length of major axis:

The measures are so discrepant that a comparison will be of no particular value except between instruments of the same class.

3rd, Position of minor axis:

Holden—Schultz	=	+7·9°	1865-6
„ —Hall	=	+1·0	1875

4th, Length of minor axis:

Holden—Lamont	=	+4·7″	1837-9
„ —Lassell	=	−7·9	1860
„ —D'Arrest	=	+0·2	1863
„ —Auwers	=	−0·4	1863
„ —Newcomb	=	+2·1	1874
„ —Hall	=	−6·4	1875

5th, Position of Star 14^m = Lassell No. 1:

Holden—Herschel	=	−8·2°	1825-33
„ —Lamont	=	−0·2	1837-9
„ —D'Arrest	=	−1·8	1863
„ —Auwers	=	+1·1	1863
„ —Schultz	=	+1·4	1865-6
„ —Hall	=	+2·6	1875

6th, Distance of Star 14^m from estimated centre of nebula:

Holden—Auwers	=	+0·5″	1863
„ —Hall	=	−0·3	1875

7th, Difference of R.A. of nebula and Star 14^m:

Holden—Herschel	=	+0·68	1825–33
„ —D'Arrest	=	−0·08	1863 (mean of 2)
„ —Auwers	=	+0·15	1863
„ —Schultz	=	−0·05	1865–6 (mean of 2)

The above discrepancies, although large, and in some cases apparently progressive, are probably due only to the intrinsic difficulty of the measures, and to the fact that the appearance of the nebula is different in different telescopes.

On the Southern Nebulæ 30 (Bode) Doradûs, and the Nebula about η Argûs. By C. E. Burton, Esq.

In the month of November 1874, while serving on the Transit of *Venus* Expedition at the island of Rodriguez, several opportunities occurred of studying the nebulæ referred to above with a silver-on-glass reflector of 12 inches aperture. The results of my work in that direction are embodied in the subsequent portion of this Note, and in two of the figures which accompany it.

30 *Doradûs* coming to the meridian at an hour which did not interfere with other work, received most of my attention. Two careful eye-draughts of this nebula, and of the stars involved in it, together with two or three other noticeable stars, were made on the nights of 1874, November 9 and 13. These sketches were combined to form the sketch laid before the Society. There was no time to spend in forming a skeleton chart of the stars upon which the nebula might be laid down, an operation which I was prepared to perform had the opportunity offered itself.

The recent sketch is placed beside a copy of Sir John Herschel's Cape drawing enlarged to nearly the same scale, and semi-reversed as regards the East and West points, I having used a Newtonian reflector.

Change in Nebula.—(1) In the Cape drawing the streak of nebulosity between the North and South loops is highly curved, and concave toward the South. In the 1874 sketch the same streak bends northward at its West extremity, from which springs a very distinct loop curving southward, which does not seem to be indicated in the earlier representation.

(2) In the Cape drawing the bright star involved in the South loop seems to be situate in a very faint region. In 1874 that knot of the nebula was sufficiently bright to render it difficult to distinguish the fainter stars involved in it. See the

"C.—Attendere placuit ad formam Saturni, eaque exhibita fuit, non quasi adjunctis orbi medio duobus aliis orbiculis, sed quasi adnatis duabus ansulis interceptis maculis, quasi foraminibus effictæ. Heinc forma ovallina, et ea sanè longiuscula, adeo ut medius quasi nucleus vix superaret trienteno totius longitudinis. Fuit autem nonnihil clarior, candicantiorque ipsis ansis. Longitudo semper protensa secundum eclipticam. Habes utcumque heic effigiatum. Diameter Martis apparuit minor sensibiliter diametro breviore Saturni."

"D.—Visi sunt adhuc distinctius Saturni satellites quasi duo cuculli hac propemodum specie."

"E.—Cùm ad Saturnum telescopio attendissem medius ille circulus albus non est mihi visus planè exquisitus, speciesque fuit prope hujusmodi."

"F.—Saturnus hujusmodi ferè fuit."

"G.—Saturnus sic se propè habuit."

"H.—Vesperi Parisiis Saturnus rotundus apparuit sine satellitibus clarissimo viro Ismaeli Bullialdo, quemadmodum etiam solitarius deprehensus fuit ab ipsomet Amanuensi mensibus Februario ac Junio telescopio majore Dygbeano videlicet, et minore Galileano."

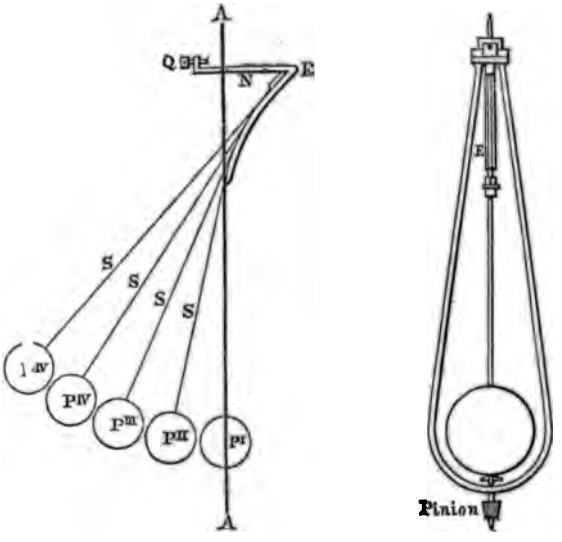
The Observatory, Crowborough,
December 7, 1875.

The Results of some Experiments with Huygens' Parabolic Pendulum for obtaining Uniform Rotation. By R. L. J. Ellery, F.R.S., F.R.A.S., &c.

In the course of some experiments I made about two years since with the view, if possible, of obtaining more uniform rotation for our barrel Chronographs than had hitherto been secured, I was induced to try Huygens' revolving Parabolic Pendulum, which appeared so perfect theoretically that I surmised as the reason it had not been more generally adopted that there must be some great practical difficulty pertaining to the application of the principle.

I was somewhat surprised too, on looking into the literature of the subject, to find so little information; and in the books within my reach in Melbourne no record of any experiments or precise trials of this kind of pendulum for securing uniform rotation. I had, therefore, nothing to guide me in my experiments except the bare principle. The earlier results I obtained were so unpro-

mising that my idea that there must be some fatal practical difficulty in the way was strengthened. Eventually, however, I succeeded in obtaining results, and under trying tests, which satisfied me that the pendulum would, with moderately precise workmanship and careful adjustment, become an almost perfect Governor where the variations of force are not greater than we generally have in chronograph trains, or, indeed, in well-constructed and balanced Equatoreals; and in two Chronographs which I had constructed for the Transit of *Venus* observations, and which were controlled by parabolic pendulums, the rotation of the barrels were practically uniform, even when such a variation of the driving weight was made as to produce a difference of 20° in the arc of the rotating pendulum. When I say *practically uniform*, I mean that, on a barrel rotating once in a minute for two hours and a half, *all similar second marks* were in an absolute straight line, and that with a fine drawing pen and a straight edge a line could be drawn accurately bisecting each second mark; in other words, its secondary rate was not a tenth of a second in two hours. As the principle of Huygens' Parabolic Pendulum may not be generally known among our members, I would beg to refer to these diagrams:—



Let A A be a vertical axis of rotation which can be driven by clockwork acting at the top or the bottom of the axis; from this axis a pendulum P is suspended in such a way that when it hangs vertical the string S lies wrapped over a curved surface E, which forms part and parcel of the vertical axis. This curve

is the evolute of a parabola, whose distance from vertex to focus is half the length of the required pendulum. Now let the axis revolve and the pendulum will fly out from its vertical position, more or less according to its weight and the driving power; the arc described by the pendulum, as it increases its distance from the vertical, will be a parabola, by reason of the string gradually unwrapping from the evolute E. Now, from the properties of the parabola, it follows that the vertical distance between the centre of rotation of the pendulum P and the intersection of the string S with the axis of rotation of the pendulum will remain constant, and therefore that the length of the pendulum remains constant at whatever arc it may rotate.

To practically secure these conditions it is necessary, first, that the evolute shall be properly and precisely made, and secondly, that it shall be so adjusted that the axis of the evolute and involute shall be coincident with the axis of rotation.

The pendulums I had constructed are *half seconds*, that is, rotating once in a second. They are suspended in a hard gun-metal frame, pivoted at top and bottom, the lower pivot resting on an end jewel, the upper pivot supported by a strong cast-iron gallows bracket, and it is driven by a contrate wheel in the clock train engaging into a pivot at the lower end of the frame. The frame is open, of the form shown in the right hand figure, to allow of the middle part of the axis of rotation being clear for the evolute and the pendulum string or rod. The evolute is fixed at M, and is capable of adjustment at right angles to the axis of rotation by a screw Q, the proper position of the curve in the other direction being practically secured by careful workmanship, more especially in the construction of the evolute itself. The pendulum consists of a spherical bob, weighing about 2½ lbs., on a steel rod about one-tenth of an inch thick, and suspended by a long and *exceedingly thin* steel spring secured to the top of the evolute at N. The regulation of the length of the pendulum is done in the ordinary way by a nut at the bottom of the steel rod. The Governor thus made with ordinary care and workmanship is by far the best of any I have had experience of, and has furnished results better, I believe, than any others used with chronographs; at the same time it is simple and inexpensive. In the course of my experiments I found it quite necessary to use the most flexible suspension possible, and the thinnest steel spring made for French clock pendulum springs appears to answer well—it is not liable to twist unless the pendulum is started or stopped suddenly, and this is prevented by a guide for the bottom of the pendulum rod. To get the proper position of the evolute:—If the time of rotation increases with an increase of arc, in other words, if it revolves slower for increase of arc, the axis of the evolute is beyond the axis of rotation, reckoning from the centre of oscillation of pendulum (that is, it is too far away from pendulum bob); and it is too near if it revolves more rapidly for increase of arc. The adjustment

is somewhat tedious, more especially because for every alteration, however slight, of the evolute a large alteration of the length of pendulum is requisite—but it is easily done with a barrel chronograph by increasing and diminishing the driving power and noting the effect, on the rate, of increased and diminished arcs of pendulum. The screw which adjusts the evolute should be moderately fine, as the final touches necessary to get accurate performance will be found very small. I found a good deal of trouble in the course of my experiments from small particles of dust getting between the curve and spring, and it will be found quite necessary to protect the pendulum from this source of imperfect performance.

I had an opportunity of testing one of these chronographs in the presence of Professor Harkness, of the Washington Observatory. It was allowed to go for about an hour, then the weight was doubled for half an hour, and subsequently halved—the arc of the pendulum varying from 10° to 33° under these changes, but the *lines of seconds* on the barrel were quite undisturbed, and a fine straight line could be drawn so as to bisect every similar second mark. Professor Harkness was somewhat astonished and pleased with the result. I showed one or two sheets marked by this chronograph to Sir George Airy, Mr. Christie, Mr. Dunkin, and Captain Tupman, and I intended to show them at the meeting of the Society, but I unfortunately mislaid them. I have no doubt, however, these gentlemen will remember the exceeding precision with which the sheets were marked.

It may be said, however, that such great precision is unnecessary especially in astronomical chronographs, and that any of the ordinary means of obtaining moderately uniform rotation are sufficient for astronomical purposes. I shall be in a great measure inclined to agree with such an opinion, but not altogether, for these reasons. This Governor, which gives nearly perfect results, is simpler and cheaper than nearly all those which only aim at very moderate accuracy; and again, anyone who has had much to do with *reading off* chronograph sheets or fillets will, I am sure, agree with me that *time is saved enormously* where *a scale* of minutes and seconds can be applied to the register, which can only be done with confidence where the rotation has been uniform. In an Observatory where much transit work (especially in Zone-observing) is done with aid of the chronograph, as at Melbourne, any means by which *reading off* can be expedited is of much more value than many would be inclined to imagine. Again, a simple means of obtaining accurately uniform rotation will be of great value in driving siderostats, and in many physical and physiological experiments; and I do not imagine there would be any great difficulty in applying this method to governing the driving apparatus of Equatoreals, the uniform motion of which, I believe, yet remains a thing to be desired.

I have on the table an apparatus, a kind of Morse's telegraphic register, governed by a parabolic pendulum, which will illustrate my description. It is devised to draw a paper fillet over rollers with great uniformity for chronographic purposes.

On the Silvering of Glass by Inverted Sugar, for Optical Instruments and Experiments. By M. Adolphe Martin.

(*Communicated by Warren De La Rue, D.C.L., F.R.S.*)

Since my last publication of the process of silvering glass in *Les Mondes*, No. of 10th December 1868, I have found it useful to introduce the following modifications:—

We prepare four solutions, which, preserved apart, undergo no change:

1° A solution of 40 grammes of crystallised nitrate of silver, in a litre of distilled water.

2° A solution of 6 grammes of pure nitrate of ammonia, in 100 grammes of water.

3° A solution of 10 grammes of caustic potash (quite free from carbonate and chloride), in 100 grammes of water.

4° We dissolve 25 grammes of sugar in 250 grammes of water; we add 3 grammes of tartaric acid, and heat to boiling, which is maintained for about 10 minutes to produce the inversion of the sugar, and the solution is then allowed to cool. We then add 50 cubic centimetres of alcohol, to hinder any subsequent fermentation, and we dilute with water to make the volume half a litre if the silvering is to be done in winter, or dilute still more if it is to be done in summer.

We will take as an example the silvering of a mirror of ten centimetres diameter. On the surface of the glass, previously dusted with a brush of badger's hair, are poured a few drops of concentrated nitric acid, and, with the aid of a pad of fine carded cotton, free from extraneous substances, the glass is carefully cleaned, rinsed with water, and dried with a perfectly clean fine linen cloth. On the surface itself is made a mixture of about equal volumes of the potash solution (No. 3) and of alcohol, and this is used to clean the surface by means of a tuft of cotton. This liquid, of a somewhat syrupy consistence, has the property of wetting the glass without running off at the edge as other liquids would do. The surface thus covered is plunged into a vessel of tolerably pure water and well rubbed with a badger-hair brush to make the alkaline coating dissolve; the face is then turned downwards into a plate containing pure water, taking care that

between the surface and the bottom of the plate there is a layer of water of at least ½ a centimetre (which may be secured by supporting the mirror by three little wedges of wood or whalebone), and by a slight rocking we carry off the liquid of the preceding washing.

In a first graduated glass measure of suitable size we pour

15 cubic centimetres of the solution of nitrate of silver, No. 1.

15 cubic centimetres of the solution of nitrate of ammonia, No. 2.

Into a second glass measure:

15 cubic centimetres of the solution of potash, No. 3.

15 cubic centimetres of the liquid of inverted sugar, No. 4; and we pour this into the first glass.

This mixture is put into a small plate, and the mirror, which was left on the water, is brought rapidly and laid upon its surface. The mirror is kept at ½ a centimetre from the bottom, as was done with the water; and is agitated gently by means of wedging in a continuous manner. If the liquids have been well prepared, the transparency of the first mixture is not impaired on pouring into it the mixture of potash and sugar. This definitive liquid ought, at the end of about half a minute, to colour itself, first pinkish yellow, then a yellowish brown, at last ink black. At this moment the silver begins to deposit itself on the border of the plate, with the colour of platinum; the glass then becomes silvered, in a very regular layer, without marked mottlings; we go on agitating it from time to time, and when the liquid, which has become turbid and greyish, covers itself with flakes of brilliant silver, the operation is finished. The mirror is removed and carefully washed under a sufficiently abundant stream of water, and after pouring quickly some distilled water over the surface, it is placed upon its edge on folded blotting paper and allowed to dry thoroughly. The surface then appears brilliant, but covered with a light bloom, which is easily removed by aid of a pad of chamois leather having upon its surface a little fine English rouge. *But if the potash is well freed from carbonate and the surface well cleaned, the silvering is perfectly brilliant and polished under this bloom, and it is not necessary to insist upon rubbing it with the pad.*

The principal accidents which may happen by reason of the inexact proportions of the mixtures are as follow:—If in the mixture of the nitrate of silver and the nitrate of ammonia the quantity of this last is insufficient, there will be on the addition of the mixture of potash and sugar a brown precipitate. If it is in excess, the silvering liquid will indeed remain clear, but it will colour itself by passing through violet tints; the white light reflected at the surface of separation of the glass and the liquid, before the silver appears, is coloured violet, and the silvering then produced is slow, very thin, dull, yellow for transmitted

light, and it never attains a sufficient thickness. [When the ammoniacal solution is well proportioned the reflected image has brown tints; the silvering is produced at the end of about five minutes, and gives a layer which is blue by transmitted light, very brilliant by reflection]. Tints greenish by reflection, and persistent mottlings occur when the glass is not sufficiently cleaned. None of these inconveniences present themselves if the foregoing directions have been followed exactly. The presence of carbonate in the potash, if it is abundant, may give a white precipitate, which becomes very quickly coloured upon pouring in the sugar: the reducing action then takes place rather in the liquid than on the surface of the plate; even in small quantity the carbonate gives rise to dull flakes on the silver film, and the rubber never polishes them well.

The degree of concentration of the solution of silver is also important. If too weak, the action is slow and incomplete, but it is easy to increase the quantity during the course of the operation. If too strong, the action is too quick, and the reduction of silver takes place chiefly in the liquid; it is very difficult to moderate it. It is always proper to make a preliminary trial, inasmuch as the concentration of the reducing solution should vary with the exterior temperature. Lastly, in removing the mirror from the water in order to plunge it into the silvering solution, care must be taken that the water does not run off from the edge: the effect would be to produce on the circumference spots of dull and badly adhering silver.

Half-Silvering.—M. Léon Foucault has also, for certain experiments, proposed the process which he calls *half-silvering*. He accomplished it by his old process, and applied it specially to the observation of the Sun by aid of a refractor. The exterior surface of the object-glass which has received this half-silvering reflects into space the greatest part of the calorific rays, while the luminous rays continue their course so as to give rise to the ordinary image. The temperature of the image of the Sun furnished by such a glass is raised so little that a coloured glass introduced to diminish at pleasure the luminous intensity is not injured, as it would be if the object-glass were unsilvered.

The half-silvering may be obtained by the foregoing process, by stopping the operation as soon as the silver begins to appear upon the glass. The glass is removed out of the bath, washed well with water, and dried; but the rubber must not be applied. A few trials will show at what moment the glass should be taken out in order to obtain a silvering to reflect more or less light at the expense of the transmitted light.

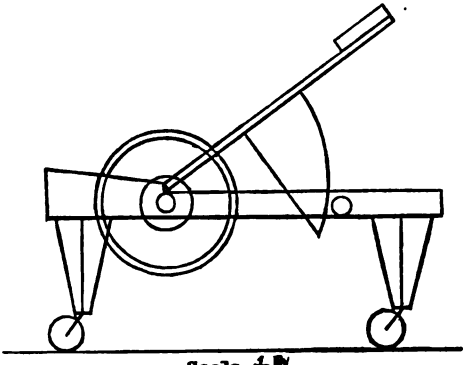
(Extracted from *Les Mondes*, No. of 17th June 1875.)

A New Form of Observing Chair. By Wentworth Erck, Esq.

This chair has now been in use some years, during which it has given entire satisfaction. It has all the advantage of a screw motion in raising the head through very small distances, while it has the great advantage of admitting of instantaneous motion through large arcs, which the screw does not. It has the further advantage of simplicity and economy.

The frame of the chair consists of a parallelogram about 42 × 21 in. and 4 inches deep, supported on French castors at a convenient height.

Twelve inches at one end of this frame is sheeted over to form a seat, and to this seat the movable back is strongly hinged.



Scale $\frac{1}{10}$.

This back carries, at 20 inches from the hinges, two arcs of a circle 20 inches radius, and of any desired extent provided the sine of the arc does not exceed the height of the chair. These arcs are made of strong hoop-iron bent to the required curvature. To the vertex of each one end of a leather strap is firmly screwed, whilst the other end of the strap is secured to a loose roller about 3 inches diameter, placed across the frame immediately behind the arcs.

Now it is evident that if this roller be made to revolve, the effect will be to wind up, or lower, the back by means of the attached arcs.

But the roller, being in a position inaccessible to the observer, is connected by saddle-girth web to another roller in a convenient position near the front of the chair.

The axis of this second roller passing through the frame carries at each end a wooden wheel about 15 inches in diameter, having a thickened edge for convenience of handling. There is also fixed on this axis a ratchet wheel 6 inches in diameter, with a pawl so placed as to be easily released by the observer. It is

clear that by releasing the pawl and pressing on the back of the chair, it will be instantly depressed through any angle; and on the other hand, by spinning round the wheel, the back, if relieved from weight, can be instantly raised through any desired angle.

If the diameter of the rollers and large wheel be respectively $2\frac{1}{2}$ and 15 inches, then a motion of the circumference of the wheel through a quarter of an inch will raise the observer's eye about one-sixteenth of an inch, corresponding to a space of a tenth of an inch between the teeth of the ratchet wheel.

The front edge of the chair should be slightly raised to prevent the body slipping forward when the back is inclined at certain angles.

For a telescope whose eyepiece is 5 feet from the Declination axis I use two of these chairs with seats at different heights, and when my feet are off the ground pull myself into approximate position by a strap hooked on to some convenient fixture.

Sherrington, Bray, Co. Wicklow,
1875, *December.*

On Celestial Photography. By Prof. Zenger.

Professor Zenger, in a letter dated Prague, November 10, 1875, writes that he has succeeded in very greatly reducing the time of exposure in celestial photography by employing "aplanatic objectives or mirrors of large aperture." He uses a new correcting achromatic lens in combination with mirrors of large aperture and very short focal length, so as to reduce the focal length to four times the aperture.

Professor Zenger also made use of the observations in the pure air of the Engadine. He states that with these arrangements he is able to get, every day that the Sun is sufficiently bright, photographs in which the corona presents itself as "a bright circular ring with the protuberances in it, if there are any. The ring on an average 1^m in height, and only in exceptional cases of nearly 2^m, and an excentricity amounting to only $2''$ or $3''$ of arc." "There is a fainter ring with broken outer layers, though often with sharply edged outlines.

"Careful observations of the Sun with my short focal refractor have shown the possibility of viewing directly the inner and most brilliant ring, if there be a coloured glass of a greenish yellow tint used.

"I cannot say whether this ring of nearly $30''$ (it passes the filar micrometer in 2^s nearly) be the chromosphere itself, or the most brillant inner layer of the corona next the Sun, but I and Professor Jafauk, to whom I showed it, saw it all round the Sun as a nearly spherical ring of scarcely perceptible excentricity to the Sun's centre.

"I therefore would regard it as the most brilliant part of the

solar corona next to the Sun's disk, and showing no sharp outline, but fading away with a very rapid decrease of brilliancy."

And in a subsequent letter, dated Prague, November 17, 1875, he has sent to the Society some copies of photographs of the Sun made by him at the beginning and end of the stormy period beginning November 6, at 6^h mean time of Prague, and ending at night, November 14.

Dates of Photographs.

		h m	
1	Nov. 6	3 0	Busch's Refractor.
1, 2	Nov. 6	3 30	Steinheil's Aplanatic.
3, 4	Nov. 14	2 20	„ „
5, 6	Nov. 14	2 35	„ „

Remarks upon two Papers by Colonel Tennant. By the Rev. Prof. C. Pritchard.

In the last Number of the *Monthly Notices* Colonel Tennant has done me the honour of referring to two articles of mine communicated to the Royal Astronomical Society. These remarks, arising from so eminent a source, require a respectful consideration from myself.

The first relates to the mode of obtaining a bright and steady image of a star, or of a wire, by reflection from quicksilver; and Colonel Tennant implies that he found some difficulty in the application of the method which I proposed in the *Monthly Notices* for January 1853. On the other hand, after long and varied experience, we find the constant application of the method not only a convenience, but even a luxury, in observations. If Colonel Tennant will do me the favour of consulting my paper he will find that the chief requisites for ensuring success are three. First, the amalgamation must be perfect; and for this end it is absolutely necessary that the surface of the copper should be clean, that is to say, it must be copper, and neither dust nor grease. Secondly, the pond of mercury must be shallow throughout, and in no part exceed (say) one-twentieth of an inch in depth. Thirdly, some ready means must be provided for skimming from the surface the very objectionable film which inevitably rises to the top, and which is due to the mere fact of amalgamation. These means are described fully in my paper, and I attribute the failures which have arisen in the adoption of the method to the non-observance of these simple but necessary precautions.

With us at Oxford the whole operation of renewing a faultlessly bright and steady reflecting surface is the work of less

than two minutes, and the surface is then so stable, and the cessation of all tremor so rapid, that we are annoyed neither by the presence of persons in the room, *nor by wind*, nor by the passage of heavy vehicles at a distance of three hundred yards. Our support for the mercury-trough, in the case of one of the instruments, is simply an iron frame, the four legs of which, after striding across the base of the instrument, rest on the stone pier.

I remember that on one occasion an eminent firm of opticians having been requested to adapt this method to a very large transit instrument, despatched a copper vessel of the dimensions of an ordinary copper preserving-pan; moreover, the bottom had been most carefully planished, and not without oil. The Nemesis was the abandonment of the method altogether.

Like many other presumed inventions, I find that I have been anticipated; but, as I at present believe, only partly so. Mr. Marth states that this method of a shallow amalgamated copper vessel was in use at Königsberg while he was a student there under the illustrious Bessel. But, as the vessel was *cup-shaped*, it seems to me a highly inconvenient form for skimming away the film, and ill adapted for the rapid destruction of tremors.

Colonel Tennant, in the same Number of the *Monthly Notices*, refers to an Ephemeris of twelve close circumpolar stars, which issued from the Oxford University Observatory in January of the present year. He complains of the smallness of the stars. Certainly I regret with him that no brighter stars exist in close proximity to the pole; but, on the other hand, I think that eleven out of twelve of these stars are not much inferior to the seventh magnitude, and are described by the late Mr. Carrington in his Redhill Catalogues as visible with a telescopic aperture of one English inch; and they are in constant use for determining the azimuthal error of the Oxford transit instrument with an aperture of less than four inches. Inasmuch as these stars are so selected that, together with those in the *Nautical Almanac*, two close circumpolars at an upper or a lower culmination are provided for every hour, I cannot but think that the arrangement must be very convenient in any Observatory where the assistants are few. I regret that I cannot entirely agree with Colonel Tennant that (even in such a latitude as that of Madras) the azimuth error of a transit instrument can be as accurately obtained from the observation of stars within twelve degrees of the pole as from an Ephemeris of far closer though fainter stars, such as that which we provided at the University Observatory.

The November Meteors. By the Rev. S. J. Perry, F.R.S.

The weather this year was unfavourable for observing the November meteors, except on the nights of the 11th and 14th. On the 11th, between 13^h 30^m and 18^h, the sky was very clear, but the moon was full. The only meteors seen were five of the first magnitude, one second, and three fourth. Only two of these were Leonids.

On the 14th the night was somewhat cloudy, but a watch was kept from 10^h till 16^h 30^m, and the following meteors were seen:—

Between	h 12 and	h 13,	3 meteors,	1 of which was a Leonid.	
„	13 „	14,	3 „	none of which were Leonids.	
„	14 „	15,	9 „	4 „	„ „
„	15 „	16,	5 „	1 or 2 „	„ „
„	16 „	16.30,	4 „	all „	„ „

The meteors were all from first to fourth magnitude, the moonlight being too strong for others.

The paths of all the meteors seen were carefully noted.

Stonyhurst Observatory,
1875, December 7.

On the Double Star 61 Geminorum. By the Rev. S. J. Johnson.

I examined this object with a 4-in. Wray on the night of December 5, the air being very clear and steady. Powers of 300 and 420 brought out the faint companion as a glimpse object. The companion of δ *Geminorum*, rated at the same magnitude by Smyth, and of a more dusky colour and difficult to observe, was quite easy to it. Not having a micrometer, I turned the instrument on δ *Orionis* by way of comparison in point of separation; but the components of 61 *Geminorum* were certainly somewhat wider than this, perhaps about 60″ apart, as Smyth states. Position-angle by estimation about 180°. It seems, therefore, much in the same state of brightness as when Mr. Sadler observed it last spring. Its magnitude now is about the same as that of the distant comes to *Aldebaran*. Owing to the distance agreeing tolerably well, may we not infer that this is the actual object observed by Smyth, that he recorded the angle of position erroneously, and consequently that variability need not be suspected? There are many instances of his marking magnitudes incorrectly, as for example γ *Delphini*.

Upton Helions Rectory, Crediton,
December 7.

Discovery of Minor Planet (157).

Another member of the Minor Planet group was discovered at Marseilles by M. Borrelly on December 1, 1875, at $10^h\ 30^m$ P.M. It was of the 12–13 magnitude. The following is its observed position on the evening of discovery:—

1875.	Mean Time at Marseilles. h m s	R.A. h m s	l.f.p.	N.P.D. ° ′ ″	l.f.p.
Dec. 1	12 8 39	4 22 4·00	+8·763	66 1 32·0	−0·4699

The planet was compared with W.B. (2) IV. 419–20, a star of the $8\frac{1}{2}$ magnitude, whose mean position for 1875·0 is—

R.A. h m s	N.P.D. ° ′ ″
4 20 47·95	66 9 47·6

The hourly motion of the planet was found to be $-3^s{\cdot}10$ in R.A., and $-16''{\cdot}0$ in N.P.D.

1875, *December* 10.

ERRATA.

Pages 8 and 9. The figures called 2 and 3 should be 3 and 2 respectively.

Page 40. For Mr. Noble read Mrs. Noble.

„ 41. The figure is reversed, right for left; it should be held before a looking-glass to present the effect as viewed in the telescope.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVI. *January* 14, 1876. No. 3.

PROFESSOR J. C. ADAMS, F.R.S., President, in the Chair.

Professor Cleveland Abbe, U.S. Meteorological Office, Washington;

William Barneby, Esq., Salmarsh Castle, Herefordshire;

The Rev. Henry Collins, Vicar of Ellerton, near Wheldrake, York;

Augustus S. Harrison, Esq., M.A., Muir College, Allahabad;

Richard Coward Johnson, Esq., Warrenside, Blundellsands, near Liverpool;

Josiah Young Messum, Esq., R.N., F.R.G.S., Controller of H.M. Packet Services, General Post Office;

Harris Charles Lindon Saunders, Esq., Leacroft House, Staines; and

Major W. H. Wardell, R.A., 3 Alexandra Terrace, Sheerness;

were balloted for and duly elected Fellows of the Society.

Observations of the Solar Eclipse, 1875, *September* 29, *made at the University Observatory, Strasburg.*

(*Communicated by Professor Winnecke.*)

This Eclipse was observed by Dr. Schur with the Heliometer which was used by him during the observations of *Venus*, December 9, 1874, in Auckland Island, and by Herr Hartwig with the Heliometer of the German Expedition to the Mauritius. Both Heliometers were again erected at Strasburg for a redetermination of their different constants, after their return from the expeditions. They have an aperture of $0^{m}\cdot076$, and their local distance is $1^{m}\cdot15$. The atmospheric conditions were by no means favourable during the Eclipse; clouds were frequently passing

and troubled the observations, so that the first two measures of Dr. Schur and one of Herr Hartwig had to be rejected.

Dr. Schur measured, with power 47, the following chords:—

Mean Time Strasburg. h	m	s	Distance of Cusps.		Errors.
			"		"
0	33	44·0	471·22	$+i$	− 0·55
	36	56·0	525·63	$-i$	− 0·62
	38	43·0	546·54	$-i$	− 1·55
	40	56·0	557·00	$+i$	+ 1·41
	42	33·5	572·41	$+i$	− 1·64
	45	2·0	588·97	$-i$	+ 3·96
	46	46·5	603·93	$-i$	− 3·71
	49	3·5	595·06	$+i$	+ 3·39
	54	1·5	597·23	$+i$	+ 0·40
0	56	17·0	598·13	$-i$	+ 0·65
1	5	11·0	529·21	$-i$	+ 1·83
	7	15·5	498·24	$+i$	− 1·89
	9	47·5	455·62	$+i$	− 0·65
	14	51·5	343·36	$-i$	− 0·16

The error in the adopted point of coincidence of the images formed by the two halves of the object-glass is put $= i$.

Diminishing the *Nautical Almanac* R.A. of the Moon by 10″·5, according to the observations by Herr Hartwig, with the Transit,* and correcting by −1″·90 the *N.A.* semidiameter of the Sun, according to Schlüter's measures with the Königsberg Heliometer,† and by −2″·30, the *N.A.* semidiameter of the Moon, on the authority of Oudemans,‡ Dr. Schur got, by taking:

dr = Correction to the adopted semidiameter of the Sun,
$d\mathrm{R}$ = " " " " " " Moon,
dx = " " " " excess of Moon's R.A. over Sun's R.A,
dy = " to excess of Moon's Decl. over Sun's Decl.

the following equation of conditions:—

$0 =$	$-16''\cdot68$	$+ 4\cdot127\, dr$	$+ 4\cdot138\, d\mathrm{R}$	$+ 3\cdot197\, dx$	$+ 2\cdot420\, dy$ $-i$
$0 =$	$-22\cdot91$	$+ 3\cdot731$	$+ 3\cdot742$	$+ 2\cdot787$	$+ 2\cdot278$ $+i$
$0 =$	$-23\cdot44$	$+ 3\cdot584$	$+ 3\cdot597$	$+ 2\cdot623$	$+ 2\cdot238$ $+i$
$0 =$	$-12\cdot64$	$+ 3\cdot444$	$+ 3\cdot457$	$+ 2\cdot455$	$+ 2\cdot209$ $-i$

* *Astron. Nachrichten*, vol. lxxxvi. p. 154.

† *Monthly Notices*, vol. xxi. p. 180.

‡ *Astron. Nachrichten*, vol. lii. p. 28.

$o = -15''.56$	$+ 3''.367\, dr$	$+ 3''.379\, d\mathrm{R}$	$+ 2''.352\, dx$	$+ 2''.201\, dy$	$-i$
$o = -17''.39$	$+ 3''.279$	$+ 3''.293$	$+ 2''.221$	$+ 2''.205$	$+i$
$o = -25''.10$	$+ 3''.238$	$+ 3''.252$	$+ 2''.144$	$+ 2''.220$	$+i$
$o = -10''.70$	$+ 3''.207$	$+ 3''.221$	$+ 2''.060$	$+ 2''.255$	$-i$
$o = -14''.49$	$+ 3''.216$	$+ 3''.230$	$+ 1''.927$	$+ 2''.382$	$-i$
$o = -22''.31$	$+ 3''.254$	$+ 3''.268$	$+ 1''.885$	$+ 2''.466$	$+i$
$o = -25''.47$	$+ 3''.722$	$+ 3''.734$	$+ 1''.864$	$+ 3''.069$	$+i$
$o = -23''.53$	$+ 3''.950$	$+ 3''.961$	$+ 1''.906$	$+ 3''.319$	$-i$
$o = -25''.45$	$+ 4''.360$	$+ 4''.370$	$+ 2''.006$	$+ 3''.746$	$-i$
$o = -46''.85$	$+ 6''.330$	$+ 6''.336$	$+ 2''.626$	$+ 5''.676$	$+i$

The simultaneous determination of the five errors would give results of no value. Solving therefore the equations, and leaving dr, $d\mathrm{R}$ in the results, Dr. Schur got:—

dx	$= + 0''.76$	$- 0''.686\, dr$	$- 0''.691\, d\mathrm{R}$	weight 9·57
dy	$= + 7''.21$	$- 0''.797\, dr$	$- 0''.797\, d\mathrm{R}$	„ 15·07
i	$= + 3''.75$			„ 13·88

Probable error of one measure $\pm 1''.53$

Herr Hartwig made his measures with power 255. They are:—

Mean Time Strasburg. h	m	s	Distance of Cusps.		Errors.
			$''$		$''$
o	34	8·3	485·53	$-i$	−1·51
	42	13·4	575·33	$-i$	+0·67
	46	35·5	597·09	$-i$	+1·08
	50	5·5	601·34	$+i$	+0·66
	53	53·5	598·85	$+i$	+1·47
o	57	13·6	589·72	$+i$	−0·33
1	6	13·6	513·35	$+i$	−1·18
	9	39·7	461·08	$+i$	−0·79
	15	14·7	325·85	$+i$	+0·37

With the above values of the adopted corrections, and using the same notation, Herr Hartwig deduced from these measures the equations:—

$o = -23''.69$	$+ 4''.062\, dr$	$+ 4''.073\, d\mathrm{R}$	$+ 3''.132\, dx$	$+ 2''.394\, dy$	$+i$
$o = -19''.61$	$+ 3''.373$	$+ 3''.387$	$+ 2''.366$	$+ 2''.197$	$+i$
$o = -19''.27$	$+ 3''.243$	$+ 3''.257$	$+ 2''.153$	$+ 2''.220$	$+i$
$o = -15''.24$	$+ 3''.197$	$+ 3''.212$	$+ 2''.025$	$+ 2''.273$	$-i$
$o = -15''.15$	$+ 3''.210$	$+ 3''.225$	$+ 1''.927$	$+ 2''.375$	$-i$

$0 = -17''.93$	$+ 3''.277\, dr$	$+ 3''.292\, dR$	$+ 1''.871\, dx$	$+ 2''.508\, dy$	$- i$
$0 = -23''.95$	$+ 3''.831$	$+ 3''.843$	$+ 1''.883$	$+ 3''.190$	$- i$
$0 = -27''.59$	$+ 4''.327$	$+ 4''.337$	$+ 1''.995$	$+ 3''.713$	$- i$
$0 = -44''.07$	$+ 6''.662$	$+ 6''.666$	$+ 2''.740$	$+ 5''.990$	$- i$

and by solving them by the method of least squares, he got—

$dx =$	$+ 0''.53$	$- 0''.681\, dr$	$- 0''.692\, dR$	weight 3·68
$dy =$	$+ 7''.58$	$- 0''.801\, dr$	$- 0''.797\, dR$	„ 6·12
$i =$	$+ 2''.39$	$- 0''.004\, dr$	$\pm 0''.000\, dR$	„ 4·43

Probable error of a single measure $\pm 0''.81$

Taking the *Nautical Almanac* R.A. of the Sun as correct, we have—

Correction to Moon's R.A.	$-9''.74$	$-0''.686\, dr$	$-0''.691\, dR$	Pr.E.	$\pm 0''.49$
Correction to Moon's Decl.	$+7''.21$	$-0''.797\, dr$	$-0''.797\, dR$	„	$\pm 0''.39$

by Dr. Schur; Auckland Heliometer.

Correction to Moon's R.A.	$-9''.97$	$-0''.681\, dr$	$-0''.692\, dR$	„	$\pm 0''.43$
Correction to Moon's Decl.	$+7''.58$	$-0''.801\, dr$	$-0''.797\, dR$	„	$\pm 0''.33$

by Herr Hartwig; Mauritius Heliometer

These corrections agree with the results of the Greenwich observations of this Eclipse given in the November Number of the *Monthly Notices*, pp. 38, 39, with due regard to the difference in the adopted value of the semidiameters of Sun and Moon.

The ending of the eclipse was observed:—

Mean Time Strasburg. h	m	s				
1	19	12	Dr. Schur	Power	47	
1	19	18	Herr Hartwig	„	155	Sky very whitish.

Taking the mean of the above corrections of the Moon's place, and using the values for the diameters of the Sun and Moon employed in the former calculations, the ending of the Eclipse is found to take place at $1^h\ 19^m\ 38''.5$ Strasburg mean time. The difference between observation and calculation, great as it appears to be, is accounted for by the smallness of the telescopes, and the extreme slowness of the rate of separation of the limb of the Sun and Moon; the distance of the centres changing only one second of arc in about nine seconds of time.

Strasburg, 1875, *Dec.* 14.

Report by the Astronomer Royal on the Present State of the Calculations in his New Lunar Theory.

In two preceding communications to the Society, which are printed in their *Monthly Notices*, 1874 January, and 1875 March, I have explained as the principles of the method proposed by me, that, in the plane of the ecliptic, there are formed the equations of areas and of *vis viva*, and, normally to the ecliptic, the simple equation of the normal forces; that these equations are used without integration; and that the peculiarity of the method consists in the following process:—that Delaunay's numerical values for every term in the detailed expansion of Parallax, Longitude, and Latitude, are adopted, every term being supplemented by addition of symbolical corrections both to the coefficient and to the argument (different for every different term); and that in this state the terms are substituted in the equations to which I have alluded; and that thus subordinate equations will be formed by which the numerical value of every symbolical correction may be obtained.

The left side of the equations, as exhibited in the paper of 1874 January, consists entirely of functions of the co-ordinates as disturbed, without explicit introduction of the disturbing forces. In these (omitting mention of the terms depending on the earth's oblateness and the terms depending on the change of plane of the ecliptic, in which no important work is yet done), the following steps are made:—

The whole of the substitutions are made to the decimal figure 10^{-7}. And these have been done with so much care, the whole in duplicate and portions in triplicate, and all subjected to irregular examination, that I would fain hope that there are no systematic errors, and very few and unimportant special errors.

There are, however, terms, whose treatment, though generally in the same form, requires distinct attention.

First, there are the terms of long period. These terms have small factors in $\frac{dv}{dt}$; and in the differentiation of every function of the ordinates, and if no special care were taken, their results would be lost in the equations. A list has been prepared, therefore, of about twenty terms in longitude, and about as many in latitude, in which the "movement of argument" is small. (The first in longitude is the Annual Equation; the last is the distance of the lunar perigee from the solar perigee. The first in latitude is the distance of lunar node from lunar perigee; and the last is the distance of lunar node from solar perigee.) The risk of error here is generally removed by adopting the rule,

that the values of $\frac{dv}{dt}$ and the like are to be taken so far in the decimal scale, that the number of effective figures in the product shall be as great as that in the multiplicand. Some of these products, repeated, will advance to 10^{-11}, or further.

Secondly, there are the terms whose movements of arguments differ little from the movement of Moon's longitude. These terms are, in general, closely related to those first mentioned. They require the same attention as the first, not because the factors in $\frac{dv}{dt}$, &c., are small, but because the factors of symbolical correction, on the right side and on the left side, approach to equality. They never require to be carried so far as those of the first series. The principal of these terms are the Evections in longitude and in latitude.

Some progress, but not great, is made in this supplementary work. It will require much of my personal attention.

Finally, for the left side of the equations, there are to be introduced the coefficients of the symbolical corrections. A considerable advance has been made in these, as applying to coefficients of angular or periodic terms; but there is yet much to be done. As applying to arguments, no part is yet done. This work of symbolical corrections will also require my own attention.

I proceed now to report on the progress in the preparation of the right side of the equations.

Different terms in the right side are multiplied by different powers of the fraction $\frac{\text{Moon's distance}}{\text{Sun's distance}}$, whose value differs little from $\frac{1}{180}$. If, then, our principal term is computed to the decimal 10^{-7}, it will suffice to compute the next to 10^{-5}, the following term to 10^{-3}, and so on. The calculation of these different powers is completed, requiring my examination.

Each of these powers multiplies a function (some of them rather complicated) of sines and cosines, of the difference between Sun's true longitude and Moon's true longitude, and of sines and cosines of multiples of that difference. If the Moon's true longitude = Moon's mean longitude + ζ, and if the Sun's true longitude = Sun's mean longitude + θ, and if $\zeta - \theta = \chi$, then the difference of the true longitudes = difference of mean longitudes + χ. In order to prepare the sines and cosines above mentioned, it is necessary to prepare the successive powers of χ to the sixth; by means of these, the several series representing the sines and cosines of the multiples of χ may be formed; and, combining these (by the usual trigonometrical formulæ) with the sines and cosines of multiples of difference of mean longitude, the sines and cosines in question will be

formed. The powers of χ are prepared, and advances are made in the other steps, all requiring my examination.

The principal risk of error in these operations, conducted by young men of small mathematical education, is in the formation of the products of sines by cosines, when the arguments of both factors are somewhat complicated.

Royal Observatory, Greenwich,
1875, *December* 17.

Addendum to the preceding Report.

I have remarked above that there are, in the Lunar Theory, certain coefficients whose values must be computed to a greater degree of accuracy than is necessary for the general mass of calculations; the selection of the terms depending on one of these circumstances: either that the inequalities which they represent go through their periodic changes in the course of many revolutions of the Moon, or that they go through their changes in a period differing slightly from a single revolution of the Moon. For the sake of placing on record more accurately the state of my own progress in the Theory, as well as for providing numbers which ought, in my opinion, to be used in their numerical form (as distinguished from a symbolical form) in all Lunar Theories, I ask leave to present to the Society, Tables of the numerical values of the Movements of Arguments to which I allude.

The unit of time which I adopt is that which in the usual expression of Moon's mean longitude in terms of radius makes $nt=t$, or which equals the Moon's periodic time divided by 2π. Then the following may be adopted as fundamental numbers; which theoretically undergo infinitesimal changes, but which for our purposes may be regarded as permanent constants; subject to corrections in the values for f and l, which it is one object of the Theory to ascertain:

D = mean angular departure of the Moon from the Sun	= +0·9251987
f = mean angular departure of the Moon from Ascending Node	= +1·0040219
l = mean angular departure of the Moon from Lunar Perigee	= +0·9915480
L = mean angular departure of the Sun from Solar Perigee	= +0·0748006

(A). The following Movements apply to inequalities of angular motion parallel to the plane of the Ecliptic.

1. *Inequalities of Long Period.*

Arguments.				Movements.
+ D	$-2f$	$+ l$		−0·0912971
+ D	$-2f$	$+ l$	+ L	−0·0164965
+ D		$- l$		−0·0663493
+ D		$- l$	+ L	+0·0084513
+ D		$- l$	− L	−0·1411499
+2D	$+2f$	$-4l$		−0·1077508
+2D	$-2f$			−0·1576464
+2D	$-2f$		+ L	−0·0828458
+2D	$-2f$		− L	−0·2324470
+2D	$-2f$		+2L	−0·0080452
+2D		$-2l$		−0·1326986
+2D		$-2l$	+ L	−0·0578980
+2D		$-2l$	− L	−0·2074992
+2D		$-2l$	+2L	+0·0169026
+2D		$-2l$	−2L	−0·2822998
+3D	$-2f$	$- l$		−0·2239957
+3D		$-3l$		−0·1990479
	$+2f$	$-2l$		+0·0249473
	$+2f$	$-2l$	+ L	+0·0997484
			+ L	+0·0748006
			+2L	+0·1496012
			+3L	+0·2244018

2. *Inequalities whose Periods differ little from the Time of the Moon's Revolution.*

Arguments.				Movements.
+ D				+0·9251987
+ D	$+2f$	$-2l$		+0·9501465
+ D	$-2f$			−1·0828451
+ D	$-2f$	$+2l$		+0·9002509
+ D	$-2f$		+ L	−1·0080445
+ D		$-2l$		−1·0578973
+ D		$-2l$	+ L	−0·9830967

Arguments.				Movements.
+ D			− L	+0·8503981
+ D			+2L	+1·0747999
+ D			−2L	+0·7755975
+2D	+2*f*	−3*l*		+0·8837972
+2D	−2*f*	+ *l*		+0·8339016
+2D	−2*f*	+ *l*	+ L	+0·9087022
+2D	−2*f*	+ *l*	− L	+0·7591010
+2D	−2*f*	− *l*		−1·1491944
+2D	−2*f*	− *l*	+ L	−1·0743938
+2D	−2*f*	− *l*	− L	−1·2239950
+2D		− *l*		+0·8588494
+2D		− *l*	+ L	+0·9336500
+2D		− *l*	+2L	+1·0084506
+2D		− *l*	− L	+0·7840488
+2D		−3*l*		−1·1242466
+2D		−3*l*	+ L	−1·0494460
+2D		−3*l*	+2L	−0·9746454
+2D		−3*l*	− L	−1·1990472
+2D		−3*l*	−2L	−1·2738478
+3D	−2*f*			+0·7675523
+3D		−2*l*		+0·7925001
+3D		−2*l*	+ L	+0·8673007
+4D		−3*l*		+0·7261508
+4D		−3*l*	+ L	+0·8009514
+4D		−5*l*		−1·2569452
	+2*f*	− *l*		+1·0164958
	+2*f*	− *l*	+ L	+1·0912964
	+2*f*	− *l*	− L	+0·9416952
	+2*f*	−3*l*		−0·9666002
	+2*f*	−3*l*	+ L	−0·8917996
	+2*f*	−3*l*	− L	−1·0414008
		+ *l*		+0·9915480
		+ *l*	+ L	+1·0663486
		+ *l*	+2L	+1·1411492
		+ *l*	+3L	+1·2159498
		+ *l*	− L	+0·9167474
		+ *l*	−2L	+0·8419468
		+ *l*	−3L	+0·7671462

The following term will require special consideration :—

+D	+L	+0·9999993

This term depends on the angular distance of the Moon from the Solar perigee.

(B). The following Movements apply to inequalities of angular motion normal to the plane of the Ecliptic :—

3. *Inequalities of Long Period.*

Arguments.				Movements.
+ D	+ f	− 2 l		−0·0538754
+ D	− f			−0·0788232
+ D	− f		+ L	−0·0040226
+ D	− f		− L	−0·1536238
+ 2D	+ f	− 3 l		−0·1202247
+ 2D	+ f	− 3 l	− L	−0·1950253
+ 2D	− f	− l		−0·1451725
+ 2D	− f	− l	+ L	−0·0703719
+ 2D	− f	− l	− L	−0·2199731
+ 2D	− f	− l	+ 2L	+0·0044287
+ 2D	− 3 f	+ l		−0·1701203
+ 2D	− 3 f	+ l	− L	−0·2449209
+ 3D	− 3 f			−0·2364696
	+ f	− l		+0·0124739
	+ f	− l	+ L	+0·0872745
	+ f	− l	+ 2L	+0·1620751
	+ f	− l	− L	−0·0623267
	+ f	− l	− 2L	−0·1371273
	+ 3 f	− 3 l		+0·0374217

4. *Inequalities whose Periods differ little from the Time of the Moon's Revolution.*

Arguments.				Movements.
+ D	+ f	− l		+0·9376726
+ D	+ f	− l	+ L	+1·0124732
+ D	− f	+ l		+0·9127248
+ D	− f	+ l	+ L	+0·9875254
+ D	− f	− l		−1·0703712
+ D	− f	− l	+ L	−0·9955706
+2D	+ f	−2l		+0·8713233
+2D	+ f	−2l	+ L	+0·9461239
+2D	+ f	−4l		−1·1117727
+2D	− f			+0·8463755
+2D	− f	−2l		−1·1367205
+2D	− f	−2l	+ L	−1·0619199
+2D	− f		+ L	+0·9211761
+2D	− f		+2L	+0·9959767
+2D	− f		− L	+0·7715749
+2D	−3f			−1·1616683
+2D	−3f		+ L	−1·0868677
	+ f			+1·0040219
	+ f	−2l		−0·9790741
	+ f	−2l	+ L	−0·9042735
	+ f	−2l	− L	−1·0538747
	+ f		+ L	+1·0788225
	+ f		− L	+0·9292213
	+ f		+2L	+1·1536231
	+ f		−2L	+0·8544207
	+3f	−2l		+1·0289697

For nearly the whole of these terms it will be necessary to carry the developments of series to one decimal place further than that which I contemplate as sufficient for final results, and, for some of them, to two decimal places further that is, to 10^{-8} and 10^{-9} respectively, instead of 10^{-7}. This will be thus explained. For such developments as that of $\left(\frac{r}{a}\cos\lceil 1\rceil\right)^2 \times \frac{dv}{dt}$, in the equation of areas, the series for $\left(\frac{r}{a}\cos\lceil 1\rceil\right)^2$ must be expressed in its usual form, with coefficients to 10^{-7}; and the series for v must be expressed with the same exactness. Suppose now that one term in their product is A . sin $\lceil$D − 2f +

where A is expressed to 10^{-7}. The corresponding term in $\frac{dv}{dt}$ is $-A \times 0{\cdot}091297 \cdot \cos|\overline{D-2f+l}|$, which is nearly $= \frac{-A}{10} \cdot \cos|\overline{D-2f+l}|$; and, if we do not express the new coefficient $\frac{-A}{10}$ to 10^{-8}, we lose a part of the valid result of the application of this term, upon which the valid conclusion as to the correction of the coefficient A (by the process of Symbolical Variations) will hereafter depend. Therefore, the whole process for forming the term in $\left(\frac{r}{a}\cos|\overline{1}|\right)^2 \times \frac{dv}{dt}$ must be so conducted that the term whose argument is $D-2f+l$ shall be correct to 10^{-8}. And subsequently, when we form $\frac{d}{dt}\left\{\left(r\cos|\overline{1}|\right)^2 \times \frac{dv}{dt}\right\}$, the coefficient will again be multiplied by $-0{\cdot}0912971$; and the product, to secure its legitimate validity, must be worked out correctly to 10^{-9}. In like manner, for the term $B \cdot \sin|\overline{f-l}|$, the first operation must be carried to 10^{-9} and the second to 10^{-11}.

For the arguments whose movements are nearly ± 1 the reasoning is somewhat different; but it leads to a conclusion almost similar, namely, that the extension of decimal places in the result must depend (in a similar manner) on the difference between the argument and the number ± 1. The small factor, however, is not here repeated.

1876, *January* 19.

Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1875.

(*Communicated by the Astronomer Royal.*)

Occultations of Stars by the Moon.

Day of Obs. 1875.	Phenomenon.	Telescope.*	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
May 12	Disapp. of 37 Leonis	E. Eq.	140	Dark	11 7 31·9	L
Oct. 16	,, ζ Arietis	Altaz.	100	Bright	9 20 16·6	J
,,	Reapp. of ζ Arietis	E. Eq.	140	Dark	10 14 37·4	C
Nov. 21	Disapp. of β Virginis	Altaz.	100	Bright	14 49 20·8	L
,,	Reapp. of β Virginis	,,	,,	Dark	15 54 30·2	L

* The clear aperture of the object-glass of the S.E. Equatoreal is 12¾ inches, of the East Equatoreal 6·7 inches, of the North Equatoreal 4·1 inches, and of the Altazimuth 3¾ inches.

Phenomena of Jupiter's Satellites.

Day of Obs. 1875.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from N.A. h m s	Observer
Mar. 4	III	Tr. eg. bisection	S.E. Eq.	220	12 27 56		WC
„	III	„ last cont.	„	„	12 34 55	12 38	WC
„	III (*a*)	„ last cont.	E. Eq.	140	12 38 5		AD
Apr. 5	I	Tr. ing. first cont.	S.E. Eq.	310	10 15 9		
„	I	„ bisection	„	„	10 17 8	10 21	M
„	I	„ last cont.	„	„	10 18 53		
„	I	Tr. eg. first cont.	„	„	12 23 17		
„	I	„ bisection	„	„	12 25 47	12 32	M
„	I	„ last cont.	„	„	12 28 7		
„	III (*b*)	Ecl. disapp.	„	„	13 8 0·1	13 6 27·5	M
13	I (*c*)	Ecl. disapp.	„	130	9 19 3·3	9 19 11·6	M
„	I	Occ. reapp. first cont.	„	310	11 31 34	11 34	M
„	I	„ last cont.	„	„	11 33 1		
„	I	„ first cont.	E. Eq.	140	11 31 55	11 34	AD
„	I	„ last cont.	„	„	11 34 19		
16	III (*d*)	Tr. eg. bisection	S.E. Eq.	220	8 40 41	8 50	WC
„	III	„ last cont.	„	„	8 50 9		
18	II (*e*)	Occ. disapp. first cont.	„	310	11 24 55		
„	II	„ bisection	„	„	11 26 44	11 26	WC
„	II	„ last cont.	„	„	11 28 44		
„	II	„ first cont.	E. Eq.	70	11 20 1		
„	II	„ bisection.	„	„	11 23 1	11 26	T
„	II	„ last cont.	„	„	11 26 30		
20	II	Tr. eg. first cont.	N. Eq.	...	8 38 20	8 43	C
„	II	„ last cont.	„	...	8 40 50		
„	I	Occ. disap. first cont.	„	...	11 4 56		
„	I	„ bisection	„	...	11 6 41	11 6	C
„	I	„ last cont.	„	...	11 8 26		
„	I	Ecl. reapp.	Altaz.	100	13 23 46·4	13 20 53·9	C
23	III	Tr. eg. first cont.	S.E. Eq.	130	11 57 59		
„	III	„ bisection	„	„	12 1 49	12 9	M
„	III	„ last cont.	„	„	12 12 27		
29	I (*f*)	Ecl. reapp.	„	220	9 42 56·5	9 43 12·7	WC
„	I	„	E. Eq.	140	9 43 19·2		AD
May 4	II	Tr. ing. bisection	„	„	13 13 16	13 10	T
„	II	„ last cont.	„	„	13 16 16		

Day of Obs. 1875.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from N.A. h m s	Observer.
May 6	II (*g*)	Ecl. reapp.	S.E. Eq.	220	8 24 56·8	8 27 31·3	M
„	II	„	E.Eq.	140	8 25 47·6		A D
„	I	Occ. disap. first cont.	„	„	8 56 33	9 0	A D
„	I	„ bisection	„	„	8 58 42		
„	I	„ last cont.	„	„	9 0 17		
„	I (*h*)	„ first cont.	S.E. Eq.	220	8 58 3	9 0	M
„	I	„ bisection	„	„	9 0 11		
„	I	„ last cont.	„	„	9 1 56		
11	III (*i*)	Ecl. disapp.	E. Eq.	140	9 2 11·2	8 58 27·6	C
13	I	Occ. disap. first cont.	„	„	10 43 30	10 45	T
„	I	„ bisection	„	„	10 44 30		
„	I	„ last cont.	„	„	10 45 30		
„	II	Ecl. reapp.	„	„	11 3 26·7	11 4 16·9	T
18	III (*k*)	Occ. disap. first cont.	S.E. Eq.	310	9 54 33	10 1	W C
„	III	„ bisection	„	„	9 59 2		
„	III	„ last cont.	„	„	10 9 50		
„	III	„ first cont.	E. Eq.	„	9 59 55	10 1	C
„	III	„ last cont.	„	„	10 9 24		
„	III (*l*)	Occ. reapp. first cont.	S.E. Eq.	„	12 4 19	12 9	W C
„	III	„ bisection	„	„	12 9 48		
„	III	„ last cont.	„	„	12 11 48		
„	III (*m*)	„ first cont.	E. Eq.	„	12 6 4	12 9	C
„	III	„ last cont.	„	„	12 13 3		
21	I	Tr. eg. first cont.	„	„	11 52 43	11 54	G
„	I	„ bisection	„	„	11 56 58		
„	I	„ last cont.	„	„	12 2 12		
22	I	Ecl. reapp.	„	140	9 54 12·2	9 54 3·6	C
June 12	II	Tr. ing. first cont.	„	„	11 25 17	11 26	T
„	II	„ bisection	„	„	11 26 46		
„	II	„ last cont.	„	„	11 28 46		
„	I	Occ. disap. first cont.	„	„	12 15 8	12 21	T
„	I	„ bisection	„	„	12 16 8		
„	I	„ last cont.	„	„	12 17 8		
„	III	Tr. eg. first cont.	„	„	12 22 52	12 28	T
„	III	„ bisection	„	„	12 25 7		
„	III	„ last cont.	„	„	12 27 21		
July 6	I	Tr. ing. first cont.	„	310	9 40 42	9 40	C
„	I	„ last cont.	„	„	9 43 42		

Notes.

(*a*) The planet was ill defined.
(*b*) Dichotomized at about 3^m 20^s before the recorded time.
(*c*) Tremulous.
(*d*) Satellite bright on dark north polar belt; sky very hazy, and definition bad.
(*e*) Light clouds; limb very tremulous.
(*f*) Definition not very good; the satellite attained its full brightness about 3^m after the recorded times.
(*g*) The satellite attained its full brightness about 3^m after the recorded times.
(*h*) Very tremulous at times.
(*i*) Doubtful; cloudy.
(*k*) Tremulous; definition very variable.
(*l*) Definition very bad, limb blurred, and sky cloudy.
(*m*) Very cloudy.

The initials W C, L, C, A D, M, T, J, and G, are those of Mr. Christie, Mr. Lynn, Mr. Criswick, Mr. Downing, Mr. Maunder, Mr. Thackeray, Mr. Jenkins, and Mr. Graham.

Royal Observatory, Greenwich,
1875, *January* 14.

Note on the Double Stars, Σ 1156 *and* Σ 1163.

By S. W. Burnham, Esq.

Baron Dembowski has called attention (*Astr. Nach.* 1979) to an error of 2^m 11^s in the Right Ascension of Σ 1163, as given in *Mensuræ Micrometricæ*. This correction brings it very near the place of Σ 1156, as the latter in the same catalogue is $2^m.3$ preceding, and 3′ north. Struve's measures are as follow:—

Σ 1156	P = 158°.5	D = 18″.64	Mags. 8·0, 10·2
Σ 1163	P = 160°.7	D = 18″.35	Mags. 7·7, 9·7

Suspecting from the similarity of these results that the two pairs were the same, I carefully examined the vicinity, and found that they were really identical, there being no star in the place of Σ 1163. The principal star of the double is Weisse VII. 1346, agreeing exactly with the place of Σ 1156 in *Positiones Mediæ*. In many instances double stars are entered twice in the several lists of Sir John Herschel, but I am not aware of any other case where this has been done in the great Dorpat Catalogue.

Chicago, 1875, *Nov.* 30.

Eclipses of Jupiter's Satellites observed at Windsor, N.S.W. By John Tebbutt, Esq.

The following table contains observations which I have been enabled to make of Eclipses of *Jupiter's* Satellites during the current year. All the observations have been made with the 4½-inch Equatoreal. A magnifying power of 265 diameters was employed in the observation of the 4th September, but in all other cases a power of 180.

Date of Obs.	Satellite.	Phase of Eclipse.	Observatory Mean Time of Phase. h	m	s	Remarks.
April 20	III	R	9	11	16·7	Faintly seen just as the planet emerged from a thick cloud.
„ 26	I	R	6	50	32·1	Planet's limb ill defined and unsteady; reappearance observed through thin cloud.
May 19	I	R	7	0	3·2	Good obs.; clear sky and excellent definition. Sat. obtained full brilliancy about $7^h\ 3^m{\cdot}1$.
July 15	III	D	6	58	20·3	Clear sky and bright moonlight; definition pretty good at both phases; disappearance very gradual. Sat. attained its full brightness about $8^h\ 58^m{\cdot}1$.
„ 15	III	R	8	45	21·4	
„ 20	I	R	5	42	5·5	Clear sky and excellent definition; twilight had scarcely disappeared. Sat. attained full brightness about $5^h\ 43^m{\cdot}2$.
„ 20	II	D	7	36	54·6	Disappearance observed with extreme difficulty, the Sat. being close to the planet's limb; obs. of reappearance some seconds late; sky clear and definition good at both phases, but Moon present.
„ 20	II	R	10	0	16·6	
Aug. 14	II	R	7	9	13·9	Definition good, but Moon present; reappearance seen through very light cirrus cloud; the Sat. obtained full brightness about $7^h\ 12^m{\cdot}8$.
„ 19	I	R	7	49	24·6	Clear sky and definition pretty good. Satisfactory observation.
„ 27	III	D	6	54	12·6	Sky beautifully clear and definition remarkably good. Sat. began to fade about $6^h\ 44^m{\cdot}7$.
„ 27	III	R	8	35	26·5	Sky beautifully clear, but definition not so good. Sat. attained full brightness about $8^h\ 42^m\ 5$.
Sept. 4	I	R	6	8	10·0	Sky clear, and planet near Moon. Obs. made in twilight, and definition extremely bad.
„ 15	II	R	6	53	21·4	Sky clear and definition good, but full Moon present. Good obs. Sat. attained full brightness about $6^h\ 57^m\ 6$.

Greenwich Times of Egypt Transit of Venus Observations, with remarks as to different Phases and Discordances in Times.

By Captain C. Orde Browne, late R.A.

The following Greenwich times of contact observations of the Transit of *Venus* at the Egyptian stations are given as bearing on the question of the probable discordances between the times of individual observers. As has been repeatedly noticed, the Greenwich times on this station are easily and accurately obtained, because the longitude of the central station on *Mokattam Heights*, Cairo, was got by the exchange of telegraph signals with Greenwich. The longitudes of *Suez* and *Thebes* were obtained by the exchange of signals with Mokattam and that of *Abbasseeyah* by triangulation. That of Rigaf, however, is likely to be undetermined beyond the rough results of sextant observations for a long time.

The Greenwich times for all but the last, may be considered final to all intents and purposes. Future scrutiny might lead to some slight modification it is true; for example, if M. Döllen made any final correction of his times on certain nights, it might affect the Thebes longitude directly; on others it might do so indirectly, by modifying the personal equation between him and myself. I am satisfied, however, that no alteration so great as $0^{s}\cdot1$, is at all likely to be made. For Transit of *Venus* purposes, therefore, the times may be considered final.

Before giving them, I would say a few words on the classification of contact observations; confining myself to bare facts as to differences in the phenomena observed to whatever cause they are attributable.

From what I have seen of reports generally, I should think that the phases of contact may best be divided into three classes.

1st. *Shadow contacts*, including all those where a connexion was observed between *Venus* and the Sun, *decidedly less dark* than the body of the planet, sometimes recorded as a faint or dark shadow, sometimes as interference lines.

2nd. *Black contact*, when the ligament appeared to be solid, and as dark, or nearly as dark, as the body of the planet; in other words, when no light could be detected across the ligament.

3rd. *Geometrical contact* between the limbs of *Venus* and the Sun. In certain cases, the only phase of contact whose time could be definitely noted was the commencement or termination of *shadow*, an observation to which Mr. Stone, I think, attaches special importance.

At Mokattam and Suez, the observation of the shadow was difficult, but "black contact" was distinctly seen and noted by all observers before the perplexing white fringe of light suddenly appeared. Geometrical contact was then a very difficult observation.

At other stations (in Egypt, at Thebes) scarcely any shadow

or ligament was seen, but geometrical contact was well observed. The fringe of light appeared at different times, both at different stations and to different observers at the same station, the larger glass as might be expected detecting it first. For example, at Thebes, Colonel Campbell, with a $7\frac{1}{2}$-inch glass, saw it at all events many minutes before Admiral Ommanney, who used half of a 3-inch glass; and at Mokattam, I with a 5·9-inch glass saw it perhaps 30 seconds before Miss Newton with a 3-inch one.

It appears from the cases where more than one kind of contact was recorded, that so long a period elapsed between the different phases, that a careful analysis of observations is necessary, and that it is desirable to take great pains to learn the exact phase recorded in each case. For example, between first shadow and geometrical contact, Mr. Hunter, at Suez, records $2^m\ 18^s$, Mrs. Campbell, at Thebes, $2^m\ 0^s{\cdot}24$, and Mr. White, at Melbourne, with a $2\frac{3}{4}$-inch glass, $1^m\ 52^s$.

Between black and geometrical contact, Mr. Hunter has $1^m\ 33^s$; while Miss Newton, at Mokattam, has $1^m\ 25^s$. Mrs. Campbell's "small black drop" at Thebes does not accord with black contact apparently at Cairo and Suez. It was later, and probably very small, for no other observer at Thebes recorded it. Between first shadow and black contact, Mr. Hunter had $45^s{\cdot}0$; and Mr. White, with a $2\frac{3}{4}$-inch glass, at Melbourne, $51^s{\cdot}0$ between first recorded shadow phase and black contact. Mr. Ellery, with an 8-inch glass, records a haze or smoky shadow $2^m\ 22^s{\cdot}4$ before contact, but a distinct black thread seen 66^s before black contact. There was much cloud, extending nearly up to the Sun, at contact at Cairo and Suez. At Thebes, the sky was quite clear.

At Mokattam Heights I had insisted on "black contact" as the phase of primary importance. The following are the times recorded for it at that station, and at Abbasseeyah, the Egyptian Government Observatory, at the foot of the hill; the director of this, Mahmoud Bey, had consulted with us, and had watched contacts on the Mokattam model.

Mokattam Black Contacts.

	Greenwich Sidereal Time. h	m	s
Mr. Newton ($4\frac{1}{2}$-inch De La Rue glass)	11	17	14·48
Miss Newton (3-inch glass)			16·79
Capt. Orde Browne (5·9-inch Lee glass)			17·90
Mahmoud Bey (6-inch about)			20·61
Mean	11	17	17·45

I should not give different weights to these observations. I had had the most model practice, but I think Miss Newton, who had but little, probably made quite as good an observation.

With equal glasses I generally am about $0^s.3$ later than the average on a model. I think the above mean is therefore likely to be a good one.

There was no good opportunity for testing personal equation before the Transit; but two days after it the telescopes were dismounted and brought close together, to enable the model to be used by all at the same time, not comparing times recorded till a set of ten observations has been made; by which it appeared, that with our own instruments, I made my mean of the contacts $0^s.33$ later than Miss Newton, and $2^s.43$ later than Mr. Newton, which I give, not for application of a correction, but rather in support of the great probability that the black contact was a very definite instant as seen by us; for the correction indicated would bring all three observers to within the same second.

Suez Contacts.

	Greenwich Sidereal Time. h	m	s
Mr. Hunter (4·6-inch glass R.A.S.) shadow	11	16	39·29
Mr. Engleson (2¼-in. glass) shadow		16	40·79
Mr. Engleson, contact fully past (black contact?)		17	10·87
Mr Hunter "full" (black contact?)		17	24·29
Mr. Hunter, geometrical		18	57·29
Mean of two (black?) contacts	11	17	17·58

This mean, as here taken, very nearly agrees with that of Mokattam, it ought to be rather later. I fear, however, Mr. Engleson's observation ought not to have equal weight with that of Mr. Hunter. Mr. Engleson had never seen a model I believe, and all must have been quite new to him, nor have I any right to interpret the words "fully past" as "black contact." It may be very close to his estimate of it; but I have not gone into the matter with him, nor do I know how to do so. He would naturally record contact sooner than Mr. Hunter, because his instrument was much smaller.

Thebes Contacts, (Geometrical).

	Greenwich Sidereal Time. h	m	s
Admiral Ommanney (half of 3-in. glass)	11	16	47·20
The Hon. Mrs. Campbell (4¼-in. glass)			51·41
Colonel Campbell (7¼-in. glass)			52·66

Dr. Auwer's contact was within a fraction of a second of that of Mrs. Campbell. I have not his final or corrected record. Giving Mrs. Campbell's observation double weight, to represent

that of Dr. Auwers as well as her own in the group, the mean becomes $11^h\ 16^m\ 50^s{\cdot}67$ This, with a correction for the different nature of contact, would be considerably earlier than Mokattam, more so, perhaps, than the difference in factor would warrant.

At Rigaf, Lieut. Watson obtained a contact with a 2-inch glass at $20^h\ 8^m\ 35^s{\cdot}9$ local mean time, which observation cannot be used till a more accurate longitude is obtained.

I cannot refrain from referring to some observations of accelerated egress likely to combine with the above.

At Melbourne, Mr. White with a $2\frac{3}{4}$-inch glass got a contact entered as "thread of light destroyed," at $3^h\ 29^m\ 15^s$ local time. As he remarks that the apex of a black drop, which he terms "the Chinaman's cap," widened just as it joined the limbs, I assume this phase to be "black contact."

Mr. Ellery, with 8-in. glass, obtained a "distinct junction of limbs" at $3^h\ 29^m\ 20^s$. If this is, as I suppose, "black contact," Mr. Ellery's time agrees very well with Mr. White's, taking the difference of size of glasses into account.

With regard to interpretation of records of phases observed, I should think the model at Greenwich would furnish a valuable means of learning what phase observers recorded approximately if they set it to represent their contact.

Of the accordance of the Egyptian photographs made by Capt. Abney, R.E., it is premature to speak yet. They appear to be very good, and are now undergoing measurement.

My own double-image micrometer measurements look fairly accordant with my observation of contact, when entered on a curve, which is all I can say now.

The positions of the Egypt stations from which the transit was observed are as follow:—

Station.	Latitude N.			Longitude E.		
	°	′	″	h	m	s
Mokattam (Cairo)	30	1	46·32	2	5	6·32.
Abbasseeyah	30	4	38·13	2	5	8·66.
Suez	29	58	22·69	2	10	13·23.
Thebes	25	41	40 ±	2	10	32·76.
Rigaf	4	44	26·5	not accurately determined.		

With regard to the accuracy of these determinations, the longitude is of primary importance. The seconds of single results in each longitude operation, uncorrected for personal equations &c., were:—

Mokattam from Greenwich	6·55, 6·64, 6·61, and 6·55.
Suez from Mokattam	6·97, 6·90, 6·69, and 6·96.
Thebes from Mokattam	26·58, 26·48, 26·63, 26·50, and 26·59.

The observations for local time were made at Mokattam and

Suez with transit instruments in the meridian (that at Suez being a portable one). At Thebes, M. Döllen observed with a Russian transit in the vertical of the pole star. At Rigaf, Lieut. Watson used a sextant. The latitude of Mokattam was got by 3 determinations of stars near the meridian with a vertical circle; that of Suez with a zenith telescope. The Russian transit, having a vertical circle, was used for latitude at Thebes; and sextant observations were made at Rigaf.

With regard to telegraph work, I would call attention to the Thebes result, because I telegraphed it on December 9th as *bad* work, the signals being scarcely perceptible and slow; yet it turns out comparatively rarely that a single representative signal is found to differ from the mean of the group to which it corresponds by a tenth of a second.

As to time observations, there is little doubt that the Russian system of observing in the vertical of the pole star enables results to be got in a few hours that I should think can be obtained on no other system. As used by Mr. Gill at Suez for observing from two stations in the same night and for skirmishing purposes generally, I should think it unrivalled. For systematic observations in a fixed observatory I do not believe it offers sufficient advantages, even compared with a portable transit in the meridian, to counterbalance the evil of the increased labour necessary for the reduction of the observations.

In conclusion, I would call attention to the barbarity of leaving the telegraph longitude connexions to Melbourne and Sydney incomplete. Mr. Gill with Dr. Auwers and the German observers made a chain of determinations extending from Berlin to Bombay, and connected it with our Suez station. So that there now exists a double chain of longitude determinations from Greenwich to Suez; one *viâ* Berlin, and the other the Alexandria, Mokattam, Suez determination given above. From Suez to Bombay is then also well determined; and an exchange was made from Madras to Batavia long since, the results of which are with Mr. Pogson, I believe. If then a simple exchange were made between the fixed observations at Bombay and Madras, and the more difficult exchange arranged between Batavia and Melbourne by the employment of transmitting stations where the cable comes to land at Java and Cape Darwin, (where it would be sufficient to send observers with chronometers, not a single astronomical instrument being necessary), longitude connexions would exist between fundamental points in America, Europe, Africa, Asia, and Australia, besides which the elements for the Delisle method of application of the observations of the *Egress* of *Venus* would be thoroughly completed.

Note on the Biblical Synodic Lunar Cycles.

By S. M. Drach, Esq.

As the Pentateuch gives the curious number 43 for a basal period (whence 430, 215, 65, 301, etc.), and also 427 (or $\frac{10}{7}$ of 299), I computed—

	d	h	m	s		d	h	m	s
43	(365	5	49	12	) =	15705	10	15	36
$531\frac{5}{8}$	(29	12	44	2·88) =		15705	9	4	30
	Solar excess					0	1	11	6

(+8ˢ per lunat.)

N.B. $5000\,\pi = 15708$; $532 = 19 \times 28$ (Chronology)

Again,

		d	h	m	s
	427 solar years are	155958	13	8	24
and	$5281\frac{1}{4}$ lunations	155958	16	28	40
	Lunar excess	0	3	20	16

($-2\frac{1}{4}$ˢ per lunat.)

N.B. $5281\frac{1}{4}$ is $\frac{125}{4}$ times 169, or $5^2\left(\frac{13}{2}\right)^2$

Combine thrice first with second, and then—

		d	h	m	s
129 + 427 = 556 years	=	203074	19	55	12
$1595\frac{1}{2} + 5281\frac{1}{4} = 6876\frac{3}{4}$ lunat. $= 573\frac{1}{16}$ lunar years	=	203074	19	42	10
Solar excess	=		0	0	13	2

(about $\frac{1}{5}$ˢ per lunat.)

573 is nearly tenfold the radius in arc-degrees.

I note these results in case modern Assyro-Egyptian researches should render them available for archaic astronomy, although, of course, the secular acceleration of the Moon, by rendering the months *retrospectively longer*, will somewhat affect the difference. The synochronism 1708 solar years$=1760\frac{5}{12}$ lunar years in *our* time is noteworthy.

1876, *January* 14.

Note on the Variable Star S *Orionis*. By the Rev. T. W. Webb.

Having been informed by Mr. Isaac W. Ward of Belfast, a very intelligent and persevering observer, armed with an excellent 4·3-inch Wray achromatic, that S *Orionis* had been seen by him on November 7, 1875, half a magnitude brighter than Baxendell's *b* and *c*, the stars at the following angles of the triangle enclosing it, I was anxious to seize the earliest opportunity of examining it, but was baffled by the persistency of cloudy weather till November 16. I then found it brighter than those stars; but subsequent observations proved that it was rapidly decreasing. November 20 it was about equal to *b*, and 0·5 mag. above *d*, its next neighbour *s p*, rated by Baxendell 11·1 mag. December 22, 25, and January 1, 1876, showed a continuous diminution, and at the last epoch its superiority over *d* was very trifling; the beautiful ruby colour, conspicuous on November 16, being hardly to be detected by my 9·38-inch mirror. By means of a graphic method, embracing the whole of my observations since its discovery, December 25, 1869, I have attempted a very rough approximation to its period, which comes out about fourteen months, but within wide limits of error, as, in addition to the coarseness of the method employed, only one probable maximum, and no certain minimum, is contained in my observations. The fluctuations, too, during the winter of 1873–4 were such as to raise a doubt as to the regularity of the variation; and, on the whole, this star requires more prolonged attention. I have purposely omitted any reference to the investigations of Prof. Schönfeld, as I have not the whole of them before me; but it is very gratifying to me to find that his far more careful comparison leads to a result not unlike, though much more reliable than, my own.

It may be interesting to remark that a suspicion of variation is attached to the next neighbour, *d* of Baxendell, which I hope to keep in view.

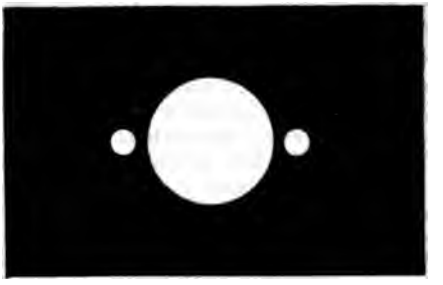
I have increased the number of stars in the triangular group around S to twelve, and a larger aperture or keener eye would probably detect more.

As an idea has been entertained of the connection of red light with variation, I have re-examined three ruby stars, formerly detected by myself, two in *Cygnus*, and one on the borders of *Orion* and *Eridanus*, but have found no sufficient evidence of change.

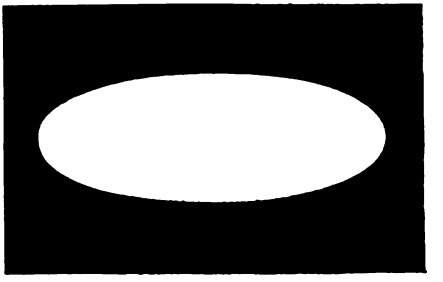
Hardwick Vicarage, 1876, *Jan.* 11.

The following woodcuts belong to Mr. Prince's Paper, "On Some Old Drawings of *Saturn*," *ante*, pp. 71–72, and are engraved

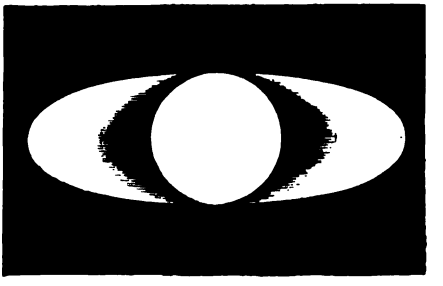
A.
June 19,
1633.



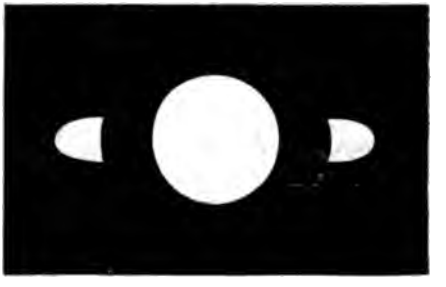
B.
April 13,
1634.



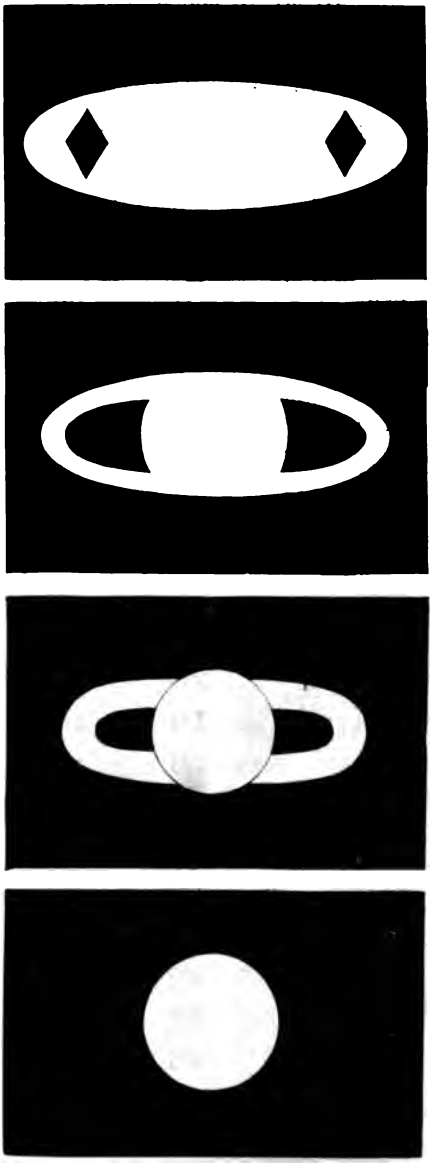
C.
Nov. 20,
1636.



D.
Jan. 11,
1645.



from the therein-mentioned tracings of the engravings of *Saturn* contained in the Lyons Edition (1658) of Gassendi's works.



E.
March 18,
1646.

F.
Dec. 8,
1650.

G.
Nov. 21,
1651.

H.
Jan. 16,
1656.

Ephemeris for Physical Observations of Jupiter 1876.

By Mr. A. Marth.

0h G.M.T. 1876.	Angle of Position of ♃'s Axis.	Longitude of ♃'s Meridian turned to the Earth.	diff.	Latitude of the Earth above ♃'s Equator.	Latitude of the Sun above ♃'s Equator.	Annual Parallax.	
	°	°	°	°	°	°	°
Feb. 15	12·20	309·65		−3·13	−3·06	−10·52	
			4352·97				−·05
20	12·02	342·62		3·14	3·06	10·57	
			3·05				+·03
25	11·88	15·67		3·15	3·05	10·54	
			3·12				10
Mar. 1	11·76	48·79		−3·16	−3·05	−10·44	
			3·18				17
6	11·68	81·97		3·17	3·05	10·27	
			3·26				25
11	11·62	115·23		3·18	3·05	10·02	
			3·32				32
16	11·60	148·55		3·19	3·04	9·70	
			3·38				41
21	11·60	181·93		3·20	3·04	9·29	
			3·44				48
26	11·64	215·37		3·21	3·04	8·81	
			3·50				56
31	11·71	248·87		3·22	3·04	8 25	
			3·56				64
Apr. 5	11·81	282·43		−3·23	−3·03	−7·61	
			3·60				70
10	11·94	316·03		3·23	3·03	6·91	
			3·64				78
15	12·09	349·67		3·23	3·03	6·13	
			3·67				84
20	12·27	23·34		3·23	3·02	5·29	
			3·70				89
25	12·47	57·04		3·23	3·02	4·40	
			3·70				94
30	12·68	90·74		3·23	3·02	3·46	
			3·71				97
May 5	12·91	124·45		−3·23	−3·01	−2·49	
			3·70				101
10	13·15	158·15		3·22	3·01	1·48	
			3·69				102
15	13·39	191·84		3·21	3·00	−0·46	
			3·65				102
20	13·63	225·49		3·20	3·00	+0·56	
			3·59				102
25	13·87	259·08		3·18	2·99	1·58	
			3·55				100
30	14·11	292·63		3·17	2·99	2·58	
			3·49				98
June 4	14·33	326·12		−3·15	−2·99	+3·56	
			3·41				94
9	14·53	359·53		3·13	2·98	4·50	
			3·34				90
14	14·72	32·87		3·11	2·98	5·40	
			3·25				84

0h G.M.T. 1876.	Angle of Position of ♃'s Axis.	Longitude of ♃'s Meridian turned to the Earth.	diff.	Latitude of the Earth	Sun	Annual Parallax.	
				above ♃'s Equator.			
	°	°	°	°	°	°	°
June 19	14·88	66·12		3·09	2·97	6·24	
			3·17				79
24	15·03	99·29		3·07	2·97	7·03	
			3·07				72
29	15·15	132·36		3·05	2·96	7·75	
			2·98				64
July 4	15·24	165·34		−3·03	−2·95	+8·39	
			2·88				58
9	15·30	198·22		3·00	2·95	8·97	
			2·79				50
14	15·35	231·01		2·98	2·94	9·47	
			2·69				42
19	15·36	263·70		2·96	2·94	9·89	
			2·60				35
24	15·35	296·30		2·94	2·93	10·24	
			2·52				28
29	15·31	338·82		2·92	2·92	10·52	
			2·44				20
Aug. 3	15·24	1·26		−2·90	−2·92	+10·72	
			2·36				13
8	15·15	32·62		2·89	2·91	10·85	
			4352·28				06
13	15·03	65·90		2·87	2·90	10·91	

The following table gives for every even hour the motion of the "longitude of ♃'s meridian turned to the Earth," corresponding to the difference of the successive values 4353° or 12 revol. 33° in five days.

G.M.T. h	0 days. °	1 day. °	2 days. °	3 days. °	4 days. °	m	0 hours. °	1 hour. °
0	0·00	150·60	301·20	91·80	242·40	0	0·00	36·28
2	72·55	223·15	13·75	164·35	314·95	5	3·02	39·30
4	145·10	295·70	36·30	236·90	27·50	10	6·05	42·32
6	217·65	8·25	158·85	309·45	100·05	15	9·07	45·34
8	290·20	80·80	231·40	22·00	172·60	20	12·09	48·37
10	2·75	153·35	303·95	94·55	245·15	25	15·12	51·39
12	75·30	225·90	16·50	167·10	317·70	30	18·14	54·41
14	147·85	298·45	89·05	239·65	30·25	35	21·16	57·44
16	220·40	11·00	161·60	312·20	102·80	40	24·18	60·46
18	292·95	83·55	234·15	24·75	175·35	45	27·21	63·48
20	5·50	156·10	306·70	97·30	247·90	50	30·23	66·50
22	78·05	228·65	19·25	169·85	320·45	55	33·25	69·53
24	150·60	301·20	91·80	242·40	33·00	60	36·28	72·55

The Ephemeris is a continuation of that given for last year in the *Monthly Notices*. The assumed daily rate of rotation is =870°·60. The "annual parallax," or the difference of the Jovicentric longitude of the Sun and Earth, is reckoned in the plane

of *Jupiter's* equator. The position of this plane is assumed in accordance with Damoiseau's determination.

The planes of the orbits of the Satellites, so far as they can be deduced from the unsatisfactory data available, have at present the following inclinations to *Jupiter's* equator:—

1876.	Sat. I.	Sat. II.	Sat. III.	Sat. IV.
Jan. 6	0°0092	0°4452	0°2062	0°3354
Mar. 6	93	·4461	·2051	·3350
May 5	94	·4470	·2041	·3344
July 4	95	·4478	·2030	·3336
Sept. 2	0·0096	0·4486	0·2020	0·3326

and their corresponding ascending nodes, reckoned from the descending node of *Jupiter's* equator on his orbit, are the following:—

1876.	Sat. I.	Sat. II.	Sat. III.	Sat. IV.
Jan. 6	57°2	63°76	278°03	330°16
Mar. 6	49·6	61·70	277·59	330·26
May 5	48·0	59·65	277·11	330·34
July 4	46·4	57·62	276·60	330·41
Sept. 2	45·1	55·60	276·07	330·46

On the Proper Motion of Bradley's Stars.

By John J. Plummer, Esq.

As the necessity for the publication of an authoritative Catalogue of Stars to take the place of the now rather antiquated compilation of the British Association is daily becoming more apparent, some results which I have arrived at with the view of determining which of the brighter stars have had their places least accurately determined may be of interest. Since the publication of the British Association Catalogue in 1847, all the brighter stars have been so frequently and carefully observed that no doubt can be entertained regarding the accuracy of the places of them to be derived from modern authorities; but, owing to the fact that their proper motions must depend almost entirely upon the old observations of Bradley and Piazzi, inaccuracies in one or other of these catalogues would injuriously affect their places after even a few years' interval. It is perfectly well known that many of the proper motions of stars in the British Association Catalogue founded on a comparison of Bradley or Piazzi with Taylor and other modern observations are quite untrustworthy; and though many of these have been corrected by the later and more accurate investigations of Messieurs Main and Stone, there yet remain not a few instances in which no better results have been published. It is a question, therefore, whether the greater

accuracy of modern observation does not to a considerable extent compensate for the less interval of the time elapsed, and whether at least as satisfactory proper motions may not now be obtained without having recourse to the older observations. Again, I do not know that we have any right to assume that proper motion is in all cases constant both in direction and amount during the long interval of 120 years which has elapsed since Bradley's observations, and indeed I believe that I have already discovered some evidence to the contrary; and lastly, the invariable use of Bradley's Catalogue, owing to the great value which time has given to it may have an undue tendency to introduce systematic error into the results obtained by its use, which it is only possible to eliminate either by a thorough discussion of all the observations that are available, or by reducing the proper motions from modern observations without their aid and comparing them with the more generally received values.

If we add, that as our knowledge of the proper motions of stars in the direction of the line of sight increases, investigations into their proper motions, at right angles thereto will have an increasing interest, it will be seen that there was more than sufficient inducement to attempt the determination of proper motions from modern observations alone; at least a comparison of results would show where the accepted proper motions are erroneous or doubtful, and a re-observation of these cases would be exceedingly serviceable (whenever a new compilation may be made) in helping to trace back the origin of the error to the older authorities, I have commenced this investigation by a comparison of the "Armagh Places of Stars" with the last published Greenwich 7-year Catalogue, there being more than 2,000 stars common to both, and very frequently an interval of 25 to 35 years between their mean dates. Moreover, the accuracy of the Armagh Catalogue left nothing to be desired, and as an authority for star places is unquestionably superior to any other of the like date. Still it was necessary to fix upon some limit of probable error below which any difference between the catalogues was to be regarded rather as error of observation than as evidence of change of place; and, after some consideration, it was determined that owing to the great care displayed in the construction of the Armagh Catalogue as well as in that of Greenwich, and having regard to the number of times that stars have been observed in each, it would be unjust to the reputation of these works to fix a higher limit than $\pm 0^{s}.25$ in Right Ascension and $\pm 2''.50$ in Declination. Whenever a star brought up by the use of the received proper motion from the earlier catalogue differed by more than this amount from the place given by the later one it was considered that there was a fair case for inquiry as to whether the proper motion employed was correct. It being but comparatively seldom that the place in either catalogue depended on less than three observations, this assumption is equivalent to the supposition that a single observation in Right Ascension in either catalogue is

liable to a probable error of about $+0^s{\cdot}216$, and in Declination of $\pm 2''{\cdot}16$, which may perhaps be held a fair estimate, though intentionally erring (if anything) upon the side of excess. In the case of stars near the pole a still greater limit of error in Right Ascension has been allowed, for though disinclined to believe that the probable error for a northern star would increase so rapidly as the secant of the Declination, it is certain that it increases in some ratio. It has been my practice to assume that if P.E.= the probable error in Right Ascension for an equatoreal star, the probable error (p.e.) for any star whose declination is δ may be expressed by the formula p.e.=P.E. sec.$\frac{1}{2}\delta$: a rule that experience has shown to be sufficiently accurate for practical purposes.

The following table will show the limits of probable error that have in effect been allowed for a single observation in R.A. in either Catalogue for each 10° of Declination:—

Declination of Star.	Assumed P.E. of single observation.	Declination of Star.	Assumed P.E. of single observation.
°	sec.	°	sec.
0	0·216	65	0·333
10	·218	70	·370
20	·223	75	·425
30	·233	80	·520
40	·248	82·30′	·599
50	·270	85·0′	0·734
60	0·307	87·30′	1·037

Notwithstanding this rather considerable latitude, not a few stars (as will be seen below) have been found which exceed the prescribed limits, and must be held as deserving of re-observation: a work that I have already commenced at the Durham Observatory, and hope to bring to a conclusion during the ensuing year.

The method that has been adopted to detect cases of discordance has been as follows. The total amount of geometrical precession in either element has been accurately computed by Bessel's constants, and the differences between the places in the chosen catalogues compared with this result. The excess of the latter over the former, having been divided by the interval between the mean dates of observation, gives the annual proper motion of the star as afforded by the two catalogues. Thus the proper motion of each of the 2,000 stars will be found and may at some time be published: at present it is only those which show large discordances that have engaged my attention. It having been the practice at the Greenwich Observatory to publish the mean places for the date of the catalogue, freed from proper motion, it has been first necessary to reduce the position back again to that of the day of observation, before comparison with the places given in the Armagh Catalogue: these latter, though reduced to 1840, are affected by the proper motions from the date of observation of each star, which in some cases is long anterior, and in others long subsequent to the above-mentioned

date. It was on account of the considerable interval of time over which the Armagh observations were extended, and of the use therein of Bessel's constants only, that I have preferred to employ these rather than the constants of Peters; but it is noteworthy, that since the values of log n given by Peters and Bessel are identical to the fifth decimal place, the resulting proper motions in Right Ascension are converted into those that would have been given by the use of Peters' constants by the addition of the constant quantity $-0^{s}\cdot00116$, *i.e.* by the application of the difference of the value of the constant m as given by these authorities. The proper motions in Declination of course require no alteration.

Unfortunately it was very soon discovered that for the present all consideration of the proper motions in Declination must be abandoned. Whether it arise from the use of different refraction tables, or from a different method of applying zenith points, the two catalogues are not comparable, the declinations given by the Armagh observers being systematically greater by a small quantity than those given by the Greenwich observers. This portion of the discussion is necessarily postponed.

The following is the comparison of the proper motions in Right Ascension of those stars which present discordances exceeding the prescribed limits, with the proper motions published and used in the Greenwich 7-year Catalogue for 1864, and included in the first six hours of Right Ascension:—

Name of Star.	No. of Observations in Green. Cat.	No. of Observations in Armagh Cat.	Proper Motion in R.A. From Green. Cat. rec.	Proper Motion in R.A. By computation. sec.	Difference. sec.	Interval of time on which the result depends. years	Approximate Declination. °
Piazzi 0.73	9	8	−0·005	+0·0070	+0·0120	27·0	+ 1
45 Piscium	5	5	−0·001	+0·0075	+0·0085	31·9	+ 7
13 Cassiopeiæ	3	6	+0·037	+0·0042	−0·0328	12·8	+66
52 Piscium	6	7	+0·012	+0·0009	−0·0111	22·6	+20
13 Ceti	7	6	+0·017	+0·0291	+0·0121	31·5	− 4
32 Andromedæ	3	4	+0·012	+0·0065	−0·0185	18·1	+39
Piazzi 0.148	5	2	+0·033	+0·0046	−0·0284	14·7	+24
Piazzi 0.189	7	8	+0·039	+0·0509	+0·0119	29·2	+ 5
Bradley 95	2	9	−0·171	+0·0685	+0·2395	36·8	+86
Bradley 122	3	2	+0·007	−0·0131	−0·0201	12·6	+21
27 Ceti	4	1	0·000	−0·0133	−0·0133	3·64	−11
32 Cassiopeiæ	3	1	−0·050	−0·0047	+0·0453	22·7	+64
45 Andromedæ	3	2	−0·039	−0·0076	+0·0314	15·5	+37
36 Ceti	3	5	+0·005	−0·0075	−0·0125	25·1	− 8
Bradley 166 *	3	1	+0·015	−0.0492	−0·0642	13·7	+78
35 Cassiopeiæ	3	5	+0·038	+0·0136	−0·0244	23·4	+64

* There is probably an error of 1 second in the R.A. given by the Armagh Catalogue; three other stars have been excluded from the list upon a like supposition.

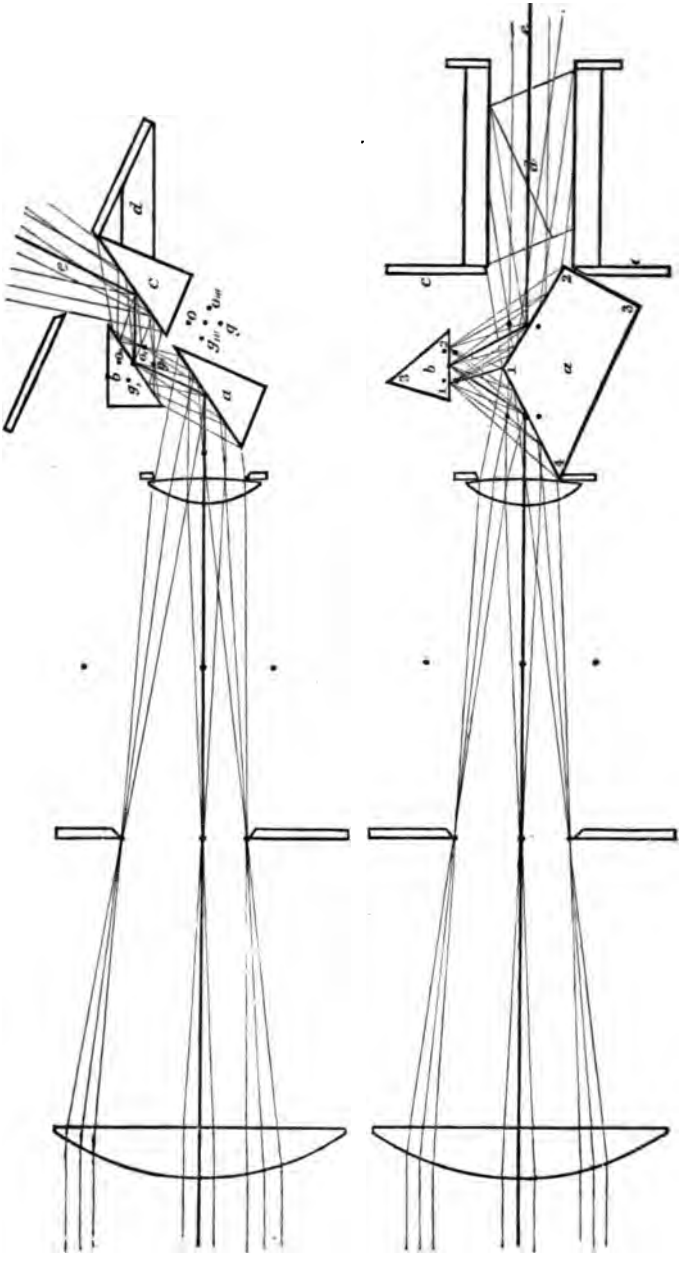
Name of Star.	No. of Observations in Green. Cat.	Armagh Cat.	Proper Motion in R.A. From Green. Cat. sec.	By computation. sec.	Difference. sec.	Interval of time on which the result depends. years	Approximate Declination. °
102 Piscium π	3	5	−0·007	−0·0277	−0·0207	20·7	+11
4 Arietis	4	6	+0·006	−0·0152	−0·0212	18·5	+16
1 Arietis	4	5	+0·009	−0·0030	−0·0120	34·4	+22
53 Ceti χ	6	5	−0·017	−0·0076	+0·0094	27·8	−11
7 Arietis	3	6	0·000	+0·0085	+0·0085	29·2	+23
112 Piscium	1	3	+0·017	+0·0380	+0·0210	15·1	+ 2
14 Arietis	3	2	+0·006	+0·0209	+0·0149	22·6	+25
66 Ceti	3	4	+0·036	+0·0180	−0·0180	19·6	− 3
29 Arietis	1	5	−0.007	+0·0022	+0.0092	28·1	+14
31 Arietis	3	3	+0·017	+0·0250	+0·0080	33·6	+12
Bradley 358	3	1	+0·051	−0·0141	−0·0651	13·1	+67
83 Ceti	2	4	+0·005	+0·0243	+0·0193	17·3	−12
Bradley 366	2	4	−0·001	−0·0844	−0·0834	9·3	+67
12 Persei	2	5	−0·002	+0·0091	+0·0111	27·5	+40
37 Arietis ο	4	5	+0·003	−0·0251	−0·0281	20·1	+15
43 Arietis σ	39	5	−0·002	+0·0070	+0·0090	32·5	+14
6 Eridani	3	1	+0·006	+0·0151	+0·0091	35·4	−24
27 Persei κ	3	4	+0·016	+0·0256	+0·0096	30·6	+45
Bradley 431	3	4	−0·025	+0·0328	+0·0578	21·5	+77
Bradley 445	1	2	+0·001	−0·0248	−0·0258	19·1	+65
Bradley 480	3	7	+0·009	+0·0216	+0·0126	28·7	+48
Bradley 496	5	5	+0·009	−0·0017	−0·0107	24·8	0
Piazzi III. 104	3	4	+0·025	−0·0019	−0·0269	24·4	+37
Bradley 569	3	1	+0·007	−0·0073	−0·0143	19·9	+ 9
49 Tauri μ	3	1	+0·003	−0·0037	−0·0067	37·0	+ 9
Piazzi IV. 31	1	5	−0·002	+0·0248	+0·0268	25·5	+41
66 Tauri τ	4	5	+0·003	−0·0052	−0·0082	33·0	+ 9
77 Tauri θ′	2	3	0·000	+0·0133	+0·0133	28·9	+16
55 Eridani	6	3	+0·005	−0·0145	−0·0195	14·3	− 9
Bradley 661	2	5	+0·016	+0·0024	−0·0136	25·9	+36
5 Aurigæ	5	5	+0·004	−0·0146	−0·0186	25·2	+39
11 Camelopardali	2	5	+0·003	−0·0183	−0·0213	26·1	+59
12 Camelopardali	1	5	+0·004	−0·0281	−0·0321	26·0	+59
4 Leporis κ	3	1	+0·003	−0·0152	−0·0182	34·9	−13
108 Tauri	2	1	+0·003	+0·0254	+0·0224	35·9	+22
8 Leporis	2	1	0·000	+0·0107	+0·0107	34·8	−14
Bradley 755	4	1	+0·007	−0·0074	−0·0144	28·3	+34
115 Tauri	9	1	−0·002	+0·0056	+0·0076	34·2	+18
6 Aurigæ	1	2	−0·004	+0·0075	+0·0115	30·4	+30

Mr. Plummer has also communicated to the Society a paper "On Astronomical Nomenclature." He proposes to designate the Minor Planets by symbols more distinctive than the present ones (which indicate only the order of discovery): for instance, (Pl.) IV. 107 would indicate a Planetoid of the fourth class, or having a magnitude between 9.0 and 9·5 when in opposition at distance unity, and 107th in order of discovery. And with regard to the Fixed Stars, down to the sixth magnitude inclusively, he proposes to divide the stars in each constellation into three groups (*a*), (*b*), (*c*), according to their magnitudes; arranging the stars in each group in order of Right Ascension or some dates previously determined on, and numbering them accordingly, those of group (*a*) from 1 to 100, those of group (*b*) from 100 to 200, and those of group (*c*) from 200 to 400; and to avoid any confusion, he suggests that the numbers might be written after the name of the constellation in the nominative case instead of before it, as Flamsteed's Nos. are marked.

On a New Form of Solar Eyepiece. By W. H. M. Christie, Esq.

In all the solar eyepieces with which I am acquainted, the reflexions by which the Sun's light is diminished take place in front of the field-lens, necessitating the use of rather large plane surfaces; a circumstance which makes these eyepieces both cumbrous and expensive. This objection may be got rid of by placing the reflecting planes between the eye-lens and the eye, as with the ordinary diagonal reflecting prism, and the pencils in this case all passing through a small circle, which is in fact the image of the object-glass as formed by the eyepiece. Very small carefully worked surfaces will therefore suffice; the only difficulty in this form of solar eyepiece being to get a wide field, a matter of small importance on the Sun, for which the restriction of the field is probably an advantage. To try this principle, I have had two solar eyepieces made, which appear to answer their purpose well.

In the first of these the pencils, after passing through the eye-lens, are reflected from the front surfaces of the three prisms, *a b c*, in succession, so adjusted that the axial pencil is reflected in each case at the polarizing angle, and placed at such a distance from the eye-lens that the image of the object-glass is formed on the second surface *b*. The rays are polarized by the two reflexions at the surfaces *a* and *b*, and then analyzed by *c*, which can be turned round an axis *d* parallel to that of the eyepiece until the light is sufficiently diminished in intensity. This is, in fact, the ordinary polarizing eyepiece applied at the eye-end, instead of in front of the field-lens, a change which makes it as easily applica-



NEW FORM OF SOLAR EYEPIECE.
By W. H. M. Christie, Esq.

ble as a diagonal prism is to any eyepiece. It is important that the prism should be so placed that b is at the place where the image of the object-glass $o_1 g_1$ is formed after reflexion from a, $o g$ being the place of the image as formed directly by the eyepiece. If the proportion of the distances between the prisms to the diameter of the pencils be as in the figure, a field of 20° is obtained without difficulty; this is quite as wide as that of ordinary eyepieces. The eye will be placed at e, where it will not be too far from its proper position to cause any practical inconvenience. It is to be remarked, that the angle of the prisms should be about 33°, so that the refracted rays, which are perpendicular to the reflected, may pass out readily, whilst those reflected internally at the second surface are sent directly back again without any risk of their reaching the eye.

The other arrangement which I have tried has the advantage of being a direct-vision eyepiece, but it involves the use of a Nicol prism, which must be of good quality. The pencils are reflected at an angle of 60° from the first surface of the prism a, which has an angle of 120°, are then incident at an angle of 30° on b, and, after reflexion from this surface, fall on the second surface of a, coming to the eye after three reflexions along the axis of the eyepiece, without deviation or lateral displacement. After these reflexions the light will be polarised, and its brightness can therefore be readily reduced to any desired amount by a Nicol prism placed at c. The distances of the prisms a b being adjusted as in the figure, a field of 10° can be obtained when the Nicol prism is used between the prisms and the eye. Without the Nicol the field would be about 20°, the eye being placed at the diaphragm c, and this extent of field could be secured by placing the Nicol between the lenses of the eyepiece and close to the eye-lens; the arrangement shown, however, appears more convenient, and the field is probably quite large enough for all practical purposes. The image of the object-glass after the first reflexion should fall on the surface b; the positions of the successive images are indicated by the dots, which show the points through which the upper, middle, and lower rays respectively of all the pencils pass after the successive reflexions. The angles 1, 2, 3, 4 of the quadrangular prism a are respectively 120°, 95°, 90°, and 55°, so that the rays fall perpendicularly on the face 23, which is silvered on the back so as to reflect them directly back again. The prism b has its angles 1, 2, 3 respectively 75°, 50°, and 55°, and the refracted rays will therefore emerge at right angles to the axis of the eyepiece.

I have tried this eyepiece on the Moon as well as on the Sun with excellent results, and I think it might be useful in examining the brighter points on the Moon's surface, as it brings out the gradation in the high lights very effectively. Both of the eyepieces would form convenient photometers on the extinction principle, for the Moon and Planets and the brighter Stars, which are difficult to manage by the ordinary methods;

all that is required to adapt them to this purpose being a small graduated circle to read off the angle turned through by the Nicol, or by the prism *c*. By applying the Nicol in place of the prism *b* in the second eyepiece, the range for photometric purposes would be greatly extended, but the object must then be brought exactly to that part of the field for which the reflexion at the first surface of *a* takes place at the polarizing angle. After two or three reflexions the light is sufficiently polarized all over the field, and this is the reason for the second reflexion at *b* in the first form before analyzing at the surface *c*. For observing critical phenomena, such as a Transit of *Venus*, it might be desirable to have the prism *c* in this eyepiece removable in case of cloud, so as to admit of viewing the Sun after two reflexions, when its brightness would be reduced to 1-150th part. After the three reflexions, the brightness is 1-1700th part of its original value, and this can be reduced to zero by turning the prism *c*; in the other eyepiece the brightness after the third reflexion is only 1-3000th part.

The figures will apply to an eyepiece of any focal length by altering the scale throughout.

I have to thank Mr. Hilger for the skill with which he has carried out the plans I have here described.

Blackheath, 1876, *January* 12.

Discovery of Minor Planet (158).

Herr Knorre, of Berlin, discovered a new minor planet in the night of January 4, 1876, while searching for the planet *Siwa*. The following are his observations :—

1876.	Mean Time, Berlin. h m s	Apparent R.A. h m s	l.f.p.	Apparent Decl. ° ′ ″	l.f.p.
Jan. 4	15 22 31	7 19 58·36	9·438	+22 1 59·3	0·705
4	16 36 27	7 19 55·57	9·542	+22 2 1·7	0·749
8	15 1 3	7 16 8·32	9·435	+22 7 39·8	0·703

The planet was of the 11–12 magnitude.

1876, *January* 12.

ERRATUM.

Monthly Notices, Vol. XXXVI. No. 1, p. 12, line 3 from bottom, *for* +2″·24 *read* −2″·24.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVI. *February* 11, 1876. No. 4.

PROFESSOR J. C. ADAMS, F.R.S., President, in the Chair.

Rev. William Jackson, M.A., Worcester College, Oxford;
Rev. Edmund Ledger, M.A., Professor of Astronomy in Gresham College, Duxford Rectory, Cambridgeshire;
John Isaac Plummer, Esq., Orwell Park Observatory, Ipswich;
Rev. Walter J. B. Richards, St. Mary of the Angels, Bayswater;
Edwin John Sykes, Esq., 5 The Quadrant, Buxton; and
John Walden, Esq., The Observatory, York Street, Jersey;
were balloted for and duly elected Fellows of the Society.

Report of the Council to the Fifty-sixth Annual General Meeting of the Society.

Progress and present state of the Society:—

	Compounders.	Annual Subscribers.	Non-resident.	Mathematical Society.	Patroness, and Honorary.	Total Fellows.	Associates.	Grand Total.
In last Report ...	195	343	5	7	2	552	45	597
Error in preceding Reports.	1	...	...	...	...	...	...	...
December 31, 1874	196	343	5	7	2	553	45	598
Since elected ...	+6	+26	...	...	...	...	...	...
Deceased	−1	− 7	...	...	...	...	− 3	...
Removals	+3	− 3	...	...	...	...	...	...
Resigned	...	− 8	...	...	...	...	...	...
Expelled	...	− 3	...	...	...	...	...	...
December 31, 1875	204	348	5	7	2	566	42	608

Mr. Whitbread's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance of last year's account	366	19	0			
„ Petty Cash Account, Dec. 31, 1874 ...	16	9	4			
				383	8	4
Dividend on £3,600 Consols	53	11	0			
„ £5,200 New 3 per Cents.	77	7	0			
„ £3,700 Consols	55	0	9			
„ £5,200 New 3 per Cents.	77	7	0			
				263	5	9
Received on account of subscriptions:						
Arrears of contributions	448	7	0			
253 contributions for 1875 ... £531 6 0						
4 do. for 1876, in advance ... 8 8 0						
	539	14	0			
32 admission fees 67 4 0						
1 do. in advance 2 2 0						
	69	6	0			
28 first contributions... ... 48 6 0						
1 do. in advance 1 1 0						
Overpaid 0 2 0						
	49	9	0			
				1106	16	0
8 composition fees...				168	0	0
Sale of publications at the Rooms of the Society				131	17	5
				£2,053	7	6

Astronomical Society, from Dec. 31, 1874, to Dec. 31, 1875.

EXPENDITURE.

	£ s. d.	£ s. d.
Salaries:—		
Editor of *Monthly Notices*	45 0 0	
Acting Assistant Secretary, Nov. 15, 1874, to Feb. 15, 1875	50 0 0	
Assistant Secretary	95 0 0	
		190 0 0
Fire Insurance:—		
Sun Fire Office	7 10 0	
Phœnix ,, ...	7 16 6	
		15 6 6
Bills:—		
Printing: Spottiswoode & Co. £199 5 6		
University Press 25 11 0		
	224 16 6	
Binding and stitching: J. Rumfitt	6 9 9	
Lithography and engraving	50 5 9	
Fittings and repairs: Whitechurch Bros. ...	31 18 0	
Cases for instruments &c.: J. Browning ...	15 14 6	
Clocks for meeting and council rooms: R. Webster	8 8 0	
Plumber and gasfitter &c.	11 11 1	
		349 3 7
Library expenses, binding, &c.		17 17 0
Turnor Fund: books purchased during year ...		29 0 0
Miscellaneous:—		
House expenses £22 18 7		
Housekeeper, Dec. 1874 to Feb. 1875 ... ... 15 0 0		
	37 18 7	
Wages...	20 18 0	
Stamps and postage	56 13 8	
Carriage of books and parcels	7 2 8	
Stationery and office expenses	23 4 1	
Expenses of meetings	17 15 6	
Coals and gas...	60 13 8	
Mrs. J. Gwilt's Annuity	8 19 0	
Sundries	35 12 11	
Powers of attorney for receipt of dividends	0 10 0	
New cheque-book	0 4 2	
Banker's commission on cheques	0 1 6	
		269 13 9
Purchase of £600 Consols, at 94⅜, including commission		567 0 0
Balance at Bankers', Dec. 31, 1875	548 18 9	
Balance in hand of Secretary of Library Committee		
,, for binding and general library expenses	32 3 0	
,, on account of Turnor Fund ...	21 0 0	
,, Petty Cash Account	13 4 11	
		615 6 8
		£2,053 7 6

Audited and found correct, subject to the observations in our Report.

E. B. Knobel,
Francis Barrow,
E. Nelson.

Assets and present Property of the Society, January 1, 1876:—

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 31, 1875				548	18	9
Due on account of subscriptions:—						
4 contributions of 4 years' standing	33	12	0			
5 „ 3 „	31	10	0			
22 „ 2 „	92	8	0			
46 „ 1 „	96	12	0			
2 admission fees	4	4	0			
2 first contributions	2	2	0			
				260	8	0
Balances in hand:—						
Petty Cash Account	13	4	11			
In hand of Secretary of Library Committee ...	32	3	0			
Do. do. on account of Turnor Fund	21	0	0			
				66	7	11

£5,200 New 3 per Cent. Consols, including Mrs. Jackson-Gwilt's Gift (£300).

£3,700 Consols, including the Lee Fund (£100) and the Turnor Fund (£450).

Unsold Publications of the Society, various astronomical instruments, books, prints, &c.

Three Gold Medals in stock.

Balance of Turnor Fund, *included in Treasurer's Account*, £164. 11*s*. 9*d*.

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	No. of copies.	Vol.	No. of copies.	Vol.	No. of copies.
I.	110	XIII.	170	XXV.	13
II.	120	XIV.	105	XXVI.	26
III.	...	XV.	155	XXVII.	2
IV.	...	XVI.	117	XXVIII.	101
V.	...	XVII.	140	XXIX.	70
VI.	64	XVIII.	167	XXX.	87
VII.	3	XIX.	71	XXXI.	123
VIII.	152	XX.	48	XXXII.	66
IX.	45	XXI.	29	XXXIII.	75
X.	180	XXII.	43	XXXIV.	105
XI.	183	XXIII.	29	XXXV.	89
XII.	19	XXIV.	24		

Index to *Monthly Notices* ... ... 209 copies.

Stock of Volumes of the *Monthly Notices* at Messrs. Williams & Norgate's:—

Vols. 1 to 32 and Index to *Notices*	71 copies.
Vol. 33	3 „
Vols. 34 and 35	24 „

In addition to the stock in hand of the volumes of the *Monthly Notices*, there are also a considerable number of separate numbers of almost every volume. These back numbers, although no complete volume can be formed from them, are available for the completion of sets.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I. Part 1	8	...	XXI. 1 & 2 (together)	70	2
I. Part 2	47	...	XXII.	169	1
II. Part 1	67	...	XXIII.	165	1
II. Part 2	27	...	XXIV.	190	2
III. Part 1	77	...	XXV.	190	2
III. Part 2	95	...	XXVI.	185	2
IV. Part 1	91	3	XXVII.	424	...
IV. Part 2	99	3	XXVIII.	401	2
V.	117	4	XXIX.	423	2
VI.	138	4	XXX.	180	2
VII.	163	3	XXXI.	186	2
VIII.	143	4	XXXII.	184	2
IX.	150	3	XXXIII.	195	1
X.	163	1	XXXIV.	150	41
XI.	172	1	XXXV.	130	7
XII.	176	1	XXXVI. (with M.N.)	200	14
XIII.	181	...	XXXVI. (without)	26	...
XIV.	377	3	XXXVII. Part 1	384	14
XV.	160	...	XXXVII. Part 2	337	10
XVI.	185	2	XXXVIII.	323	2
XVII.	160	5	XXXIX. Part 1	326	9
XVIII.	163	2	XXXIX. Part 2	363	6
XIX.	159	1	XL.	433	2
XX.	170	2	XLII.	492	15
XXI. Part 1	214	...			
XXI. Part 2	100	...			

Index to *Memoirs* ... ... 681 copies.

Instruments belonging to the Society.

The Council are deeply indebted to one of our Fellows, R. J. Lecky, Esq., who kindly volunteered to inspect the Society's instruments, with the object of identifying the separate instruments, and of ascertaining their present condition. In consequence of the limited space at disposal in our late apartments at Somerset House, most of the instruments were unavoidably deposited in the basement rooms, partly occupied by the Assistant-Secretary for domestic purposes. Instruments remaining for a long period in damp, underground apartments are very likely to become dilapidated, and some had been in these rooms since the Society was first located in Somerset House. To ascertain their present condition, Mr. Lecky devoted some time to the examination of the general state of each of the old instruments, a few of which were found to be very much out of repair; but the Council trust that the improved accommodation at Burlington House will prevent their further deterioration, for, although they are for the most part obsolete, they are worthy of the most careful preservation as historical instruments employed in former well-known astronomical investigations.

The Council have very great pleasure in inserting the following copious extracts from Mr. Lecky's very full report:—"In taking a general view of the instruments, I cannot but regret to find their sadly dilapidated condition; many are broken or decayed, some irretrievably so, and others have important parts lost; still, enough remain to give the collection an amount of interest and real value, of which few, if any, of the Fellows are aware. There are several instruments which are peculiarly interesting from their novelty and ingenuity, which are either not mentioned in the printed list, or merely given under some very ordinary appellation; while there are more of considerable historic interest, some of which are of value as good observing instruments, and others may be classed as mere curiosities, but still useful as showing the progress of construction.

"In preparing the list of instruments, I have kept as much as possible to the names and order in which the old list has, for years back, been printed, retaining the special names by which some of the instruments have been known, as I think it would be unjust to the memory of the several former owners to make any alteration therein, or to let their names drop. A few of these instruments I fail to recognise, and some are lost. I have appended to each instrument in the list a short description of its use, and the state in which it is at present. Any general repair of these could not, of course, be entertained; still I think that such instruments as the *Lee* and the *Brisbane* Circles ought to be cleaned and prevented from further decay by a coat of varnish, or even paint, which might be done at a small cost. And, may I here venture a suggestion which, I trust, you will not consider

obtrusive. There have been recently a few very valuable gifts of modern instruments; these require especially to be cared for, and, if lent, I conceive that there ought to be a substantial guarantee for their safety. I also find that there are several instruments lent, some for many years, and others which it is doubtful will ever be forthcoming. I would suggest that any of these which can be reached should be accounted for, and returned if not in actual use, and, where the value of the instrument may require it, that the borrower should insure it against fire, or sea risk, if sent abroad."

All the instruments in the printed catalogue in last year's report have been identified by Mr. Lecky, excepting the following. The Council, however, hope that some of these apparently missing instruments may yet be found, therefore they are, for the present, all included, as usual, in the printed list:—

No. 11 Universal quadrant, by Abraham Sharp
„ 21 The *Reade* transit
„ 28 *Sheepshanks* Instrument No. 2
„ 32 „ „ „ 6
„ 49 „ „ „ 23
„ 64 „ „ „ 38
„ 66 „ „ „ 40
„ 68 „ „ „ 42
„ 71 Portable Altazimuth Tripod.
„ 73 Two Biquartz and Nicol's prisms.

The Council regret that they have been unable to obtain any satisfactory information respecting *Sheepshanks* instrument No. 6, which had been lent to the late Rev. Jonathan Cape. They have ascertained that the executor of that gentleman is also deceased, and that at the sale by auction of Mr. Cape's effects two astronomical telescopes were included in the sale catalogue. Having been informed that a sister of Mr. Cape, the only remaining representative of the family, might possibly be able to give some information respecting the destination of the telescope, one of the Secretaries communicated with that lady. In her reply she enclosed a letter from Mr. Cape's solicitor, of which the following is an extract:—"On receiving your letter and the one accompanying it, requesting the return of the telescope, I sent both to the auctioneers employed, and requested information. They wrote in reply as follows:—'On referring to our sale catalogue, we find Lot 249, a valuable and powerful 6-ft. brass cylinder terrestrial and celestial telescope, with 5-in. object-glass &c., was sold at the auction for 17*l.* 10*s.*, but whether that is the one alluded to by Miss Cape we cannot tell. Lot 250, a smaller ditto, with four eyepieces, *was not sold*, and we doubt not that Mr. Cape's brother took it away, or had it sent away.'" Miss Cape, in her reply to the Secretary, states that "the large telescope referred to by the auctioneers, which sold for 17*l.* 10*s.*, belonged to my brother Jonathan; the smaller one.

Lot 250, was, I have no doubt, the missing telescope. It was *not* 'taken away' by my late brother, the Rev. W. Cape, of Peterborough, I know, and, if left to be sent away, I fear it must have been stolen, as a large quantity of mathematical papers belonging to my brother Jonathan, which were left in the house to go to the printer, were lost, and nothing could ever be heard of them; * * * and being now left alone, I feel powerless to do anything about it." There is no doubt that the telescope referred to under Lot 250 is identical with the *Sheepshanks* instrument No. 6, which the Council fear must now be considered lost to the Society.

In consequence of the loss of *Sheepshanks* instrument No. 6, in the manner described above, and of other instruments believed to have been lost, the Council have resolved that the loan of instruments shall be granted in future for one year only, subject to renewal, if still required at the expiration of the year.*

The following is a complete list of the instruments belonging to the Society:—

No. 1. The *Harrison* clock,
„ 2. The *Owen* portable circles, by Jones,
„ 3. The *Beaufoy* circle,
„ 4. The *Beaufoy* transit instrument,
„ 5. The *Herschelian* 7-foot telescope,
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich,
„ 7. The *Smeaton* equatoreal,
„ 8. The *Cavendish* apparatus,
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's),
„ 10. The Variation transit instrument (late Mr. Shearman's),
„ 11. The Universal quadrant, by Abraham Sharp,
„ 12. The *Fuller* theodolite,
„ 13. The Standard scale, by Troughton and Simms,
„ 14. The *Beaufoy* clock, No. 1,
„ 15. The *Beaufoy* clock, No. 2,
„ 16. The *Wollaston* telescope,
„ 17. The *Lee* circle,
„ 18. The *Sharpe* reflecting circle,

* *Extract from the Minutes of the Council* 1876, *January* 14:—'Mr. Dunkin reported that there are several instruments which are known to have been in the possession of the Society, and which cannot now be satisfactorily accounted for:—It was resolved that the Secretaries in every November shall go through the list of the Society's instruments, and send to each person to whom any instrument belonging to the Society has been lent, a circular desiring him either to return the instrument to the Society's rooms before the following January meeting, or to make a fresh application for it; and it was further resolved that the Secretaries should report to the Council the result of all such communications.'

No. 19. The *Brisbane* circle,
„ 20. The *Baker* universal equatoreal,
„ 21. The *Reade* transit,
„ 22. The *Matthew* equatoreal, by Cooke,
„ 23. The *Matthew* transit instrument,
„ 24. The *South* transit instrument,
„ 25. A Quadrant, by Bird (formerly belonging to Captain Cook),
„ 26. A Globe showing the Precession of the Equinoxes.

The *Sheepshanks* collection:—

„ 27. (1.) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2.) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3.) $4\frac{6}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatoreal stand and clock movement.
„ 30. (4.) $3\frac{1}{4}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5.) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
„ 32. (6.) $2\frac{3}{4}$-inch achromatic telescope, about 30 inches focal length; one terrestrial and four astronomical eyepieces. This instrument was lent to the Rev. J. Cape, and is believed to be lost.
„ 33. (7.) 2-foot navy telescope.
„ 34. (8.) A transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
„ 35. (9.) Repeating theodolite, by Ertel, with folding tripod stand.
„ 36. (10.) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.
„ 37. (11.) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.
„ 38. (12.) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

No. 39. (13.) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye end reading to single minutes; horizontal circle 9 inches diameter in brass reading to single minutes.

„ 40. (14.) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; a deal box with heavy stand for theodolite; a box containing the Y piece of level; two large and three small ground glass bubbles divided; a box containing level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires.

„ 41. (15.) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length, stand, rider-level, and fittings.

„ 42. (16.) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17.) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18.) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. The circle is divided on silver, and is read to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

„ 45. (19.) 5-inch reflecting and repeating circle, by Lenoir, of Paris.

„ 46. (20.) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.

„ 47. (21.) Box sextant; reflecting plane and level.

„ 48. (22.) Prismatic compass, by Troughton and Simms.

„ 49. (23.) Mountain barometer.

„ 50. (24.) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.

„ 51. (25.) Ordinary $4\frac{1}{2}$-inch compass with needle.

„ 52. (26.) Dipping needle, by Robinson.

„ 53. (27.) Compass needle, mounted for variation.

„ 54. (28.) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.

„ 55. (29.) Box of magnetic apparatus.

„ 56. (30.) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.

„ 57. (31.) Box sextant and glass plane artificial horizon, by Troughton and Simms.

No. 58. (32.) Plane $2\frac{3}{8}$ speculum, artificial horizon, and stand.
„ 59. (33.) $2\frac{1}{2}$-inch circular level horizon, by Dollond.
„ 60. (34.) Artificial horizon, roof, and trough; the trough $8\frac{1}{4}$ by $4\frac{1}{4}$ inches.
„ 61. (35.) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36.) A pentagraph.
„ 63. (37.) A noddy.
„ 64. (38.) A small Galilean telescope, with object-glass of rock crystal.
„ 65. (39.) Five levels.
„ 66. (40.) 18-inch celestial globe.
„ 67. (41.) Varley stand for telescope.
„ 68. (42.) Thermometer.
„ 69. (43.) Telescope, with the object-glass of rock crystal.
„ 70. Portable equatoreal stand.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 73. Two Biquartz and Nicol's prisms.
„ 74. Registering spectroscope, with one large prism.
„ 75. Camera and chemicals in box.
„ 76. Two five-prism direct-vision spectroscopes.
„ 77. Cradle for telescope.
„ 78. $9\frac{1}{4}$-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal, or star dial.

The following instruments are lent, during the pleasure of the Council, to the several parties undermentioned:—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 12. The *Fuller* theodolite, to the Director of the Sydney Observatory.
„ 14. The *Beaufoy* clock No. 1, to the Astronomer Royal for the Transit of *Venus* Expedition.
„ 16. The *Wollaston* telescope, to the Astronomer Royal for the Transit of *Venus* Expedition.
„ 22. The *Matthew* equatoreal to Mr Brett.

From the *Sheepshanks* collection:—

„ 27. No. 1, to the Astronomer Royal for the Arctic Expedition.

very carefully fitted instrument, complete with the exception of one eyepiece and some smaller fittings. The telescope is $7\frac{3}{4}$ inches long and $1\frac{1}{8}$ inch in diameter. The compass needle is 5 inches long.

No. 13. The Standard Scale, by Troughton and Simms, 1833. This consists of a cylindrical tube 1·12 inch in its exterior diameter, with palladium points or pins let in, on which the division lines are cut. The first foot is divided into tenths of inches, and then marked at 1′, 1′·5, 2′, 3′, 4′, and a mark at each end 5 feet apart, and lettered D, *d*, also the same on the reversed side lettered B, *b*. There are three unbedded thermometers divided to 0°·5, the normal temperature being 60°·78 Fahr. The rollers on which the scale is intended to be supported are not to be found.

No. 17. The *Lee* circle. A 2-foot circle with stone base and brass pillars, contained in two boxes. The object-glass is 2 inches in diameter and 30 inches focal length; two direct and two diagonal eyepieces, and three levels.

No. 18. The *Sharpe* reflecting circle. A 10-inch reflecting circle by Troughton and Simms, of the usual type, with three verniers; complete with the exception of a small reading lens.

No. 19. The *Brisbane* circle cannot be identified at present with certainty. It is supposed to be the large altitude and azimuth circle in the glass case at the far end of the instrument room. This instrument is in a sad state of dilapidation from rust and dirt, but it does not appear to be otherwise in bad repair.

No. 20. The *Baker* universal equatoreal is a small but very strongly made instrument, the telescope $1\frac{1}{8}$ inch in diameter and 14 inches focal length; two eyepieces, compass, and four levels; the whole fitted in a mahogany case. The different parts are mostly well made, but coarse circular racks and pinions. It is a curious and interesting toy.

No. 22. The *Matthew* equatoreal, by Cooke. A thoroughly well-finished instrument; object-glass 4 inches aperture and 50 inches focal length, mounted on an equatoreal stand.

No. 23. The *Matthew* transit is a modern well-finished instrument; object-glass $2\frac{1}{2}$ inches aperture and 30 inches focal length. Some of the smaller fittings are missing. The rider-level is sound, but the meridian wire is broken; the stand is of iron and in good repair.

No. 24. The *South* transit, by Troughton. Object-glass 4 inches in diameter and focal length 86 inches; micrometer eyepiece and two setting circles with attached levels. The Y supports for the pivots are believed never to have been received, and there appears to be no axis level.

No. 25. Captain Cook's quadrant, by Bird. A ship's quadrant 18 inches radius, framed in mahogany, the arc divided on silver, the vernier reading to single minutes.

The Gold Medal.

The Council have awarded the Gold Medal to M. Le Verrier, for his investigations of the Theories of *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and for his Tables of *Jupiter* and *Saturn*. The President will lay before the meeting the grounds of this award to our distinguished Associate after the Annual Report is read.

Publications of the Society.

The Council regret that the publication of Volume XLI. of the *Memoirs* referred to in last year's Report, containing collected accounts of physical observations of Total Eclipses of the Sun, has been so long delayed. Nearly all the illustrations are, however, now finished, and a considerable portion of the letter-press is in type, and the Council are assured that the work will probably be in the hands of the Fellows in the ensuing summer.

Volume XLII. was published in December. It contains the five following papers:—

1. Report on Observations of the Total Eclipse of the Sun on December 11–12, 1871, made by order of the Government of India, at Dodabetta, near Ootacamund. By Lieut.-Colonel J. F. Tennant, R.E., F.R.S.

This paper is illustrated with four representations of the eclipse during the totality drawn from the original negatives. Six photographs were taken, but the fifth was very faint and the sixth defective, and Mr. De La Rue, who, at the request of Colonel Tennant, undertook the general superintendence of their reproduction for the *Memoirs*, selected photographs Nos. 1 to 4 for engraving, believing that they show everything that can be gathered from the series. The plates were engraved at the expense of the Government of India.

2. The Total Eclipse of the Sun, 1874, April 16. By E. J. Stone, Esq., M.A., F.R.S., her Majesty's Astronomer, Cape of Good Hope.

The eclipse was observed by Mr. Stone in Namaqualand, South Africa. His station at Klipfontein was about 3,000 feet above the level of the sea. This paper is also illustrated with several wood-engravings of the eclipse, principally exhibiting the forms of the corona as seen by different observers.

3. Catalogue of Micrometrical Measurements of Double Stars, made at the Temple Observatory. By J. M. Wilson, Esq., M.A., and G. M. Seabroke, Esq.

4. Measures of 484 Double Stars, made at Mr. Edward Crossley's Observatory, Bermerside, Halifax. By Mr. J. Gledhill, F.R.A.S.

5. Proper Motions of 406 Southern Stars. By E. J. Stone, Esq., M.A., F.R.S.

A brief notice of the last paper is given in a subsequent section of the Report.

The frequent application for our *Monthly Notices* from Societies and foreign astronomers, and also from the general public, is a good example of the appreciation of the contents of the *Notices*. Volume XXXV., lately published, contains several important papers, which fully maintain the high character which our popular monthly serial has attained.

Obituary.

The Council have to deplore the loss of the following Fellows and Associates during the past year, some of whom were constant attendants at our meetings and former members of the Council.

Fellows:—Carl L. C. Becker, Esq.
R. C. Carrington, Esq., F.R.S.
W. S. Davis, Esq., LL.D.
Murray Gladstone, Esq.
Lieut.-Col. John Jones.
Rt. Hon. Sir Edward Ryan, F.R.S.
Rev. Professor W. Selwyn, D.D., F.R.S.
Charles B. Vignoles, Esq., F.R.S.

Associates:—Professor F. W. A. Argelander.
Professor H. L. D'Arrest.
Monsr. Claude L. Mathieu.

Carl Ludwig Christian Becker was born at Ratzeburg, in the Grand Duchy of Mecklenburg Strelitz, on July 16, 1821. He received his general education at the Gymnasium of Ratzeburg, of which his father was the head master. On leaving school he chose for himself the profession of a mechanician and his father at first put him with Repsold, of Hamburg. He then studied in the works of Krafft, of Vienna, and subsequently in those of Steinheil, at Munich. In 1849 he came to London, where his mechanical ingenuity was soon recognised, and in 1858 he became manager for Messrs. Elliott Brothers, Electrical Engineers and Opticians. In 1873 he became a member of their firm and continued to work hard at his business until within a few days of his death.

We may say, without the slightest fear of exaggeration, that there is hardly anyone who has, within the last ten or fifteen years, pursued physical science in England who will not look upon the death of Mr. Becker as a real loss. He showed himself to be most ingenious and accurate in everything he undertook, and at the same time his obliging and courteous manner won for him the friendship of all with whom he was brought into contact.

Lord Lindsay took Mr. Becker with his party to observe the

Eclipse of 1870, near Cadiz; he was more fortunate than some other members of the Spanish Expedition, and obtained polarimeter measures of the intensity of the atmospheric polarisation during totality, as well as a drawing of the corona. He became a Fellow of our Society in January 1874, and died on April 3, 1875, from an attack of bronchitis.

Richard Christopher Carrington was born on the 26th of May 1826, at Chelsea. He was the second son of Mr. Richard Carrington, a brewer, at Brentford, in Middlesex. At seven years old he was sent to a school kept by a Mr. Faithful, at Hedley, where he remained until his father sent him to be prepared for college in the house of a clergyman named Blogard. In 1844 he entered at Trinity College, Cambridge, and in 1848 he took his degree, obtaining the place of 36th wrangler.

His father had intended him for the Church; but, as Mr. Carrington says, in speaking of himself in the preface to his *Redhill Catalogue*, "the tenour of my mathematical studies at the University of Cambridge, acting on mechanical propensities to which I had always been addicted, gradually made it clear to me that I was more naturally adapted for the pursuit of some physical science involving observation and mechanical ingenuity" than for a profession like the Church.

The Astronomical lectures of Professor Challis, which he had attended while a student at the University, gave the final impulse which led him, on leaving Cambridge, to prepare himself systematically for the work of an observatory. The consent of his father was given without opposition; and as his probable future means promised him the opportunity of pursuing his selected occupation on his private resources, it was, as he says, "with the object of acquiring experience and of avoiding wasteful and injudicious expense," that he applied for and held for nearly three years the appointment of Observer in the University of Durham. The Observatory had not long been founded, and was but poorly supplied with instruments. The results of his labours here were not very satisfactory to himself, but the accounts of his attempts at organised work while at the Observatory will be found in a little 8vo volume published in 1852.

Finding that there was but little chance of his being supplied with fresh instruments, he determined to abandon the Durham Observatory, and to establish one of his own. He had, however, while at work in the little University town, found good opportunities for reading, and had formed a plan for completing the survey of the heavens which had been commenced by Bessel and Argelander, and had only been carried by them as far as the eighty-first degree of north declination. And at the same time he determined to advance upon their survey by employing a meridian instrument of sufficient power to include stars of the 10th magnitude. After long search for a fitting

locality he determined on building a house, with an observatory attached, at Redhill. This he furnished with a transit-circle (now at the Radcliffe Observatory, Oxford) similar to the Greenwich instrument, though smaller, having a telescope of 5-in. aperture and 5½-feet focal length. The instrument and its adjustments are carefully described in the preface to the *Redhill Catalogue*. There was also a 4½-inch equatoreal, which was used for roughly observing the stars in the polar zone and for making a preliminary or working catalogue.

The site for the observatory was fixed upon in June 1852; but the real work of observing was not commenced till 1854.

The survey of the polar zone, which he then began, occupied three years, during which time he catalogued the places of 3,735 stars within a distance of 9° from the pole. Each star, whatever its magnitude, was observed at least three times, and those near the pole were observed more frequently. These observations were also thoroughly reduced and catalogued, and maps corresponding to the catalogue were engraved on copper in nine sections of convenient size.

In addition to the labour of the actual observations and the reductions for the catalogue, considerable time was expended in determining the errors of his instruments, and in making a preliminary or working catalogue of 4,400, from which the 3,735 stars spoken of above were selected.

When the work was ready for the press Mr. Carrington applied to the Admiralty for assistance in printing the volume. The official consideration of the application occupied some weeks, and M. Le Verrier having accidentally heard that the publication was for the time at a standstill, offered to provide for the immediate appearance of the work as a part of the next volume of the *Annales* of the Paris Observatory. The acceptance of M. Le Verrier's offer was, however, rendered unnecessary by the decision of the Admiralty authorities, and the catalogue was published in 1857 in a small folio form.

The labour which had been expended upon the work soon attracted attention, and two years later the Council of our Society decided on bestowing on Mr. Carrington the highest mark of their approval by awarding him the Gold Medal for the year 1859. In presenting the medal, Mr. Main, in his presidential address, remarked that "No one could read the introduction to the *Redhill Catalogue* without gaining an idea of the positive zest with which Mr. Carrington seemed to grapple with difficulties and to conquer them one after another as they occurred."

Professor Schwerd, of Speyer, had, between the years 1826 and 1828, made a catalogue of some 680 polar stars which fell within the zone surveyed by Carrington; Schwerd's observations had been reduced and catalogued by Oëltzen, but of this Carrington was not aware when he commenced his labours. Upon making the discovery, he brought up the places of the 680 stars to his own epoch, and compared them with his own results.

This comparison greatly increased the labour of preparing his catalogue, but gave occasion, as Mr. Main says, "for a most elaborate and instructive dissertation on the whole theory of precession, nutation, and aberration, and especially on the application of it in the case of stars very near the pole." This dissertation, which is contained in the introduction to the *Redhill Catalogue*, is itself a remarkable production, and though the author disclaims any novelty, it will repay the attentive study of any astronomer who may be engaged in observations similar to those of Mr. Carrington.

But to proceed to the subject with which Mr. Carrington's name will, probably, in the future be even more closely connected than with the polar zone of stars. While in 1852 he was superintending the progress of the building of his observatory at Redhill, and was kept for a time from access to instruments, he was led into the study of some series of drawings of the Sun's disk in the possession of our Society. At that time Schwabe's discovery of the periodicity of Sun-spots had but recently been made, and the corresponding periodicity in magnetic disturbances had just been pointed out independently by both General Sabine and Professor Wolf. Carrington was anxious to retrace the dates of maxima and minima of past Sun-spot periods, and was much impressed with the capricious manner in which observations of the solar phenomena had commonly been taken up and laid aside again. As might be expected there were considerable discrepancies in the results of previous observers as to the elements of the position of the Sun's axis and its period of rotation. Carrington, therefore, determined that he would devote himself to a close and methodical record of Sun-spot phenomena for an eleven-year period. There was the personal advantage that he could make the study a subject of secondary importance to the star catalogue which he was about to commence. As he expressed it, "the observation of the stars required the hours of the night, and afforded little matter for speculation; the observation of the Sun was a day-task, and presented more variety and interest."

In order to carry out his plan it was necessary for him to devise a simple system of observation which should be more accurate than any that had been before adopted. The method he pursued did not occur to him at once in its final form, but grew out of a notion of making the disk of the Sun its own circular micrometer, and the process of reduction was successively improved, and more than one volume was commenced and put in the fire as means of simplifying the process came into view by practice and trial.

The image of the Sun was projected on a screen placed at such a distance from the eyepiece of his $4\frac{1}{2}$-inch equatoreal telescope that the Sun's disk projected upon the screen had a diameter of about 11 inches. In the focus of the telescope he placed two bars of flattened gold wire at right angles, or very nearly at right angles, to one another, and turned *approximately* into the position

of being inclined 45 degrees on each side of the meridian or parallel of declination. The telescope was fixed and the image of the solar disk was then allowed to pass across the field, and the times of contact of the Sun's limbs and the spots with each of the bars was noted. This operation was repeated three or four times, and from the observed interval of time between the successive contacts the positions of the spots with regard to the Sun's centre were determined. This simple method, requiring no micrometer or clockwork, enabled him to determine the heliographic latitude and longitude of a small spot with an error when near the apparent centre of the Sun's disk of only a few minutes of arc upon the Sun's surface. Besides these measurements, the spots and groups of spots upon the Sun's disk were carefully drawn upon every available occasion, and the work was regularly carried forward for a period of $7\frac{1}{2}$ years, from November 9, 1853, to March 24, 1861. The observations were systematically reduced as time went forward, and they were finally discussed in a ponderous quarto volume published in 1863 with funds from the Royal Society's grant.

But to return to the results of his labours. At the time when Carrington commenced his undertaking, the position of the Sun's axis and the time of his rotation had been at various times roughly determined by Laugier, Böhm, Petersen, and Kysœus; but the determinations were founded on the observations of only a few spots which had been selected without due regard being paid to their being spots suitable for the purpose of measurement. Carrington speedily found that the large and irregular spots were unfitted for the purpose, owing to the rapid transformations taking place in their form from day to day; and small and circular spots when in the neighbourhood of other spots or groups were also found to be unsuitable, owing to the repulsive action which spots appear to exercise upon others in their immediate neighbourhood. Carrington, therefore, selected observations of small isolated spots from his series; and, from a comparison of a large number of their motions, determined the position of the Sun's axis with a precision that had not before been approached.

In determining the period of rotation he found that those spots whose latitudes were great had a drift backwards upon the Sun's surface, so that the rotation period determined from them was longer than that determined from similar spots situated nearer the Sun's equator.

On carefully tabulating the drift of spots in various heliographic latitudes he found that there was a difference of more than two days in the rotation period of spots on the solar equator and in those of spots in latitudes $+ 50°$, which is about the extreme limit north and south at which spots usually appear. He further succeeded in showing that the daily drift of different parts of the photosphere follows such a law that the rotation of a spot in heliographical latitude l in one solar day may be fairly represented by the expression $865' \mp 165 . \sin \frac{7}{4} (l - 1°)$.

This important discovery was entirely due to his laborious series of observations and their careful reduction. Previously, indeed as early as 1845, Dr. Peters had satisfied himself that the solar spots had what he called proper motions of their own. But earlier observers had failed to reduce these proper motions to any law, and thus the great systematic drift of the photosphere had not till then been brought to light.

During the year 1858 Carrington's labours in this interesting field of investigation were interrupted by the death of his father, which necessitated his taking the management of the Brentford Brewery, a business of some magnitude. His new occupation did not, however, cause him entirely to abandon his astronomical pursuits. He continued to find time for the supervision of the solar work and for the publication of several interesting papers in the *Monthly Notices* embodying his most important conclusions.

Amongst Carrington's papers in the *Monthly Notices* especial reference ought to be made to a paper published by him in 1858, "On the Evidence which the observed Motions of the Solar Spots offer for the existence of an Atmosphere surrounding the Sun;"* papers "On the Distribution of the Solar Spots in Latitude between the years 1854 and 1858" and "On certain Phenomena in the Motions of Solar Spots."

In the 20th volume of the *Monthly Notices* he published a description of an intensely bright outbreak which he observed in the area of a great solar spot on September 1, 1859. This eruption, which only lasted a few minutes, appears to have been accompanied by a synchronous disturbance of the magnetic needle. No similar outbreak had been noted either before or since, and fortunately Carrington's observations were confirmed by Mr. Hodgson, who happened to be observing the Sun at the same moment at Highgate.

The reader should also refer to a paper "On Dr. Soemerring's Records of the Solar Spots made between the years 1826 and 1829," *Monthly Notices*, vol. xx., p. 71, and a paper "On the Distribution of the Perihelia of the Parabolic and Hyperbolic Comets in relation to the Motion of the Solar System in Space," which was published in the XXIXth volume of the *Memoirs*. Out of the 133 parabolic and hyperbolic orbits which he considered, he found that the perihelia of 61 lie in the hemisphere of which α *Columbæ* is the pole, or the hemisphere from which the Sun is moving, while 72 lie in the other hemisphere, towards the pole of which the Sun is assumed to be moving; the mean angular distance between α *Columbæ* and each perihelion coming out 95° 36′: a result which other evidence shows must be regarded as nugatory and vitiated by uncontrolled conditions,

* Mr. Carrington was subsequently led to modify the conclusions which he draws in this paper.

among which the principal is probably the unequal distribution of discoveries of comets in the northern and southern hemispheres of the Earth.

Mr. Carrington joined our Society on March 14, 1851, and he served as one of the Honorary Secretaries from February 1857 to February 1862, and during this period was indefatigable in his activity in the service of the Society. He was also a Fellow of the Royal Society, to which he was elected on June 7, 1860. In 1856 he made a visit to the Continent, and gave an interesting report on the condition of the Observatories at Bonn, Bilk, Göttingen, Gotha, Leipzig, Halle, Dessau, Berlin, Hamburg, and Altona. This visit served to draw attention to Heinrich Schwabe's labours, and in the following year Mr. Carrington was commissioned to transmit the medal of our Society to the aged Astronomer of Dessau for his long-continued labours, which had resulted in showing the eleven-year periodicity of Sun-spots.

In 1865 Mr. Carrington was attacked by severe illness, from which he never completely recovered; and though his love for astronomy remained, his active connection with our Society ceased. After disposing of the brewery, he retired to a lonely spot at Churt, near Farnham, in Surrey, where he built an observatory on the top of a detached conical hill which rises abruptly to a height of some 60 feet from the surrounding country and is known as the Middle Devil's Jump. Here he erected some large instruments, which are described in the 30th volume of the *Monthly Notices*; and at his house near the Observatory, on the 27th November 1875, he died, from the rupture of a blood-vessel on the brain. He has left our Society a legacy of £2000.

Murray Gladstone was the fifth son of Robert Gladstone, Esq., of Liverpool, where he was born on the 14th of February, 1816. He was educated at the Royal Institution, Liverpool, where he acquired some distinction as a scholar. As he showed a very decided turn for drawing and machinery, his father applied to the late George Stephenson to take him under his care. This introduction to the great railway engineer led Mr. Gladstone to follow this profession for several years. He was for some time employed in making surveys for railways, as well as in executing many works connected with them. Amongst others, the Viaduct over the river Weaver on the Chester and Crewe Railway was built under his immediate superintendence, and it remains a monument of his constructive ability. An advantageous opening having presented itself in the East India house of Ogilvy, Gillanden, & Co., with which his family was already connected, Mr. Gladstone gave up his profession as an engineer for the more lucrative pursuits of commerce. He went to Calcutta, where he remained for several years, and by his talents acquired a foremost place among the merchants of that city. Soon after his return to England he established the firm of Gladstone, Latham,

& Co., in Manchester, as a branch of Ogilvy & Co., and he resided until quite recently at Broughton near that city. There he constructed an observatory, in which much of his leisure time was spent; and on leaving Manchester for Penmaenmawr, North Wales, where he had built a country house, he erected at this new residence a still larger observatory, with all the latest astronomical appliances. He was elected a Fellow of this Society on May 11, 1860. In consequence of failing health during the last year or two, Mr. Gladstone was contemplating an early retirement from business, in which he never ceased to take an active interest, when, on the evening of August 23, 1875, while walking along the shore at Penmaenmawr, returning home from fishing, he was seized with a fit or some affection of the heart, and died suddenly in the sixtieth year of his age, deeply mourned by his numerous friends and acquaintances. He has left a widow, daughter of Mr. Hinde, of Lancaster, and five children.

Lieut.-Colonel JOHN JONES was born at Bath in the year 1800. He belonged to a military family, his father and grandfather having served in the army, the former in the Life Guards. He received his earlier education in France, and in 1819 he proceeded to India as a cadet. Being posted to the 46th Regiment of Native Infantry, he accompanied his regiment to Assam in April 1823, and was afterwards most actively and prominently engaged during the whole of the Burmese War, receiving a medal for general service for the conquest of Assam, and a clasp for Ava. Colonel (then Captain) Jones also served in many parts of the Bengal Presidency. He held the appointment of Quartermaster-General, and had charge of the Intelligence and Secret Service Department, for which service he received the special thanks of the Governor-General, Lord Amherst, and of his Commander-in-Chief, General Richardson.

On the termination of hostilities, in 1826, Captain Jones was selected to survey the newly conquered province of Assam and its dependencies, especially the boundary line along the eastern Himalaya range, extending 450 miles in length, and was appointed the British Commissioner for that purpose. In consequence, however, of the large number of astronomical observations necessary for the survey, and of the great exposure to the glare of the snowy range along the Himalaya Mountains, his eyes became so affected that he was obliged to return to England to consult an oculist, and eventually this weakness of sight led to his retirement from the service. In consideration of his eminent services, the Directors of the East India Company unanimously granted to him the pension of his rank as captain.

On his return from India Colonel Jones resided for some time in Wales, and afterwards at Adsett Court, near Gloucester, where he erected a small observatory, with a revolving dome, in which was mounted the transit instrument which had done him

such good service in the Indian Survey, and a sidereal clock with a mercurial pendulum. He also had a Gregorian reflector mounted on a Varley stand. His observations were chiefly meridional, and were made with the accuracy of a skilled observer. He had also in his possession some valuable repeating instruments, in the use of which he had great experience.

In 1873 Colonel Jones left Adsett Court for Cheltenham, where he had at one time formerly resided, but owing partly to his declining health, and partly to the unfavourable position of his house for astronomical observations, his instruments remained unmounted. In the spring of 1875, after suffering from bronchitis, he went to Torquay, in the hope of obtaining some restoration of his health. Here he died on April 7, 1875, having been a Fellow of this Society nearly forty years, his election dating on May 8, 1835.

The Right Hon. Sir Edward Ryan was born on the 28th of August 1793. His early education was received at a private school, and in the autumn of 1810 he matriculated at Trinity College, Cambridge, where he was the friend and contemporary of Sir John Herschel, Mr. Babbage, and Dr. Peacock. Graduating in 1814, he directed his attention to the study of law, and in 1817 was called to the Bar at Lincoln's Inn, where he pursued his profession with great success. At this time his personal acquaintance with some of the founders of the Royal Astronomical Society, naturally created in his mind an interest in scientific pursuits, and particularly in Astronomy, although it is not known that he ever undertook anything in the way of scientific investigation. His acquaintance with such men as Herschel, Babbage, and other astronomers led him to join this Society soon after its foundation, his election dating so far back as February 1820. Mr. Ryan's acuteness as a lawyer speedily attracted the attention of the Government, and in 1826 he accepted the office of Puisne Judge of the Supreme Court of Calcutta, receiving at the time the honour of knighthood. In 1833 he was promoted to the Chief Justiceship of that Presidency. During his residence in Calcutta his genial nature was much appreciated by the European residents, and his pleasant and hospitable home in Garden Reach was always open to all new arrivals from England, or to welcome the faces of old friends. It has been remarked that "the genial Chief Justice was the life and soul of society in Calcutta." Sir Edward retained the office of Chief Justice till January 1843, when he permanently returned to England. Soon after his arrival home he was sworn in a Privy Councillor, so that the country might have the benefit of his experience in Indian Appeals to the Judicial Committee of the Privy Council, a duty which he discharged for many years. In 1851 he received the appointment of Assistant-Controller of the Exchequer, an office which he held till 1862.

The country has had the benefit of Sir E. Ryan's services down to the end of his long life, and it may truly be said that he died in harness. When the question of filling the junior offices of the Civil Service by competition, rather than by patronage, was decided by the establishment of the Civil Service Commission, Sir Edward's administrative abilities caused him to be selected to superintend the experiment, and consequently, by an Order in Council dated May 21, 1855, he was named first Commissioner. The office being an unpaid one, he still retained the Assistant-Controllership of the Exchequer till 1862, in which year the Commission was established on a permanent footing. Under the presidency of Sir E. Ryan, the duties of the Commission have been gradually increasing yearly, the mere test examination being followed by limited competition, to be soon succeeded by open competition as at present. During the twenty years that Sir Edward was at the head of this Commission, he was its guiding spirit, giving to it his time and thoughts with a tact and sagacity rarely surpassed in the public service. In addition to his permanent duties, Government availed themselves of Sir Edward's advice and experience as a Railway Commissioner, in 1846, and in other ways. He also took a great interest in the prosperity of the University of London, of which he was a member of the Senate, and for a short period after the death of Mr. Grote, he served as Vice-Chancellor. He was elected a Fellow of the Royal Society in 1860.

Sir Edward married, in 1814, Louisa, daughter of William Whitmore, Esq., of Dudmaston, Shropshire. His death took place at Dover, where he had just gone for his vacation, on the night of Sunday, August 22, 1875, after an illness of four days, and within a week of completing his 82nd year. He retained his consciousness and vigour of intellect to the end. His kindly face and stately figure will long be missed, not only by his official colleagues, but also by society generally, in which he has always been much esteemed.

William Selwyn,* D.D., Canon of Ely, and Lady Margaret Professor of Divinity in the University of Cambridge, was born in 1806, and was the eldest of three sons, all of them distinguished.

After leaving Eton, he entered St. John's College, Cambridge, in 1824, and soon began to gather the laurels of University honours. For three years successively he carried off Sir W. Browne's medal for the best Greek Ode; and in one of these years, 1826, he gained all the Browne Medals, a triumph which has, it is said, been only achieved three times in the course of a century. In this same year he also carried off the Craven

* For much of the matter in this notice, the compiler begs to tender his acknowledgments to the author of the Johnian magazine *The Eagle*.

acquainted, and commenced a correspondence, and subsequently a warm friendship, in these genial terms: "Sir, permit me to introduce myself to you through the medium of our mutual, warm, but rather distant friend, the Sun."

It is, indeed, in connection with Solar Astronomy that the name of William Selwyn will be best known and longest remembered in this Society. For the whole of one of the eleven-year periods of apparently maximum and minimum solar energy (viz. from 1863 to 1873 inclusive) he caused to be taken at Ely a very regular and very valuable series of Solar "Autographs," as he playfully termed his photographic pictures of the Sun's disk, chiefly with the view of helping the solution of the vexed question of the relation of Planetary configurations to the abundance or paucity of solar spots. He hardly thought himself that any such connection existed, though, as is well known, other and very eminent physicists entertain a different opinion, "*Adhuc sub judice lis est*," therefore. It may be observed that these photographs are the work of Mr. Titterton, of Ely, and were taken by means of a 6-inch achromatic, by Slater, of London, and possess great beauty and distinctness of detail, and will be of great value by way of reference and comparison with the equally valuable Kew series, now being discussed at the Kew Observatory, at the expense of Mr. De La Rue.

As regards the lamented Canon's personal disposition and qualifications, his sympathies were indeed of the widest. Whatever the occasions might be which commended themselves to his heart—whether home or foreign missions, the relief of spiritual destitution, or the relief or education of the poor, or the furtherance of the institutions of his loved University, he was always ready with speech or sermon, with active exertion or liberal contribution. Few were there, moreover, at Cambridge or elsewhere, who have not felt the charm of that exquisite, and melodious, and persuasive voice, or who cannot recall to mind some of those words of wit and wisdom which seemed ever to be falling without effort from his lips.

It was in the year 1866 that the equestrian accident occurred to him which, though he recovered from it for the time, there can be little doubt caused in the end a premature decline in his bodily powers, and cut short his valuable life. Whilst laid on his couch, previously to his recovery, he carefully watched, as far as he was able, the remarkable shower of November meteors by which that year was made memorable. But the effects of the shock to his system told, subsequently, more and more upon the Professor, and manifested itself in a paralytic affection which began slowly to pervade his bodily frame, though not his mind, and on April 23, 1875, his spirit passed away to a yet higher and brighter existence, with a "hope full of immortality."

Professor Selwyn was a valuable member of the Committee

for the Revision of the authorized version of the Old Testament; and from the commencement of the work to the day of his death the subject occupied much of his best thoughts and attention.

To the last day of his life also the Professor was occupied with the correction of the proof-sheets of a Lecture "On the Pastoral Office," and his interest in the subjects connected with our noble science continued also to the last unabated, and he expressed only very shortly before he died his admiration of the beautiful spectacle presented by the Moon one evening, and of the planet *Jupiter*. On Thursday, April 29, his mortal remains were laid in the cemetery at Ely, by the side of those of his brother-in-law, the late Dean Peacock.

Charles Blacker Vignoles was born at Woodbrook, in the county of Wexford, on the 31st of May 1793, his father, Captain Vignoles, of the 43rd Regiment of Light Infantry, having been stationed in Ireland at that time. Captain Vignoles died of yellow fever at Guadaloupe, in 1794, and his widow survived him only a few weeks. Their only son, a boy but a few months old, was exchanged as a prisoner of war against a young French lieutenant, receiving a commission in the 43rd Regiment by way of recompense for his own orphan condition, and in recognition of his father's merits. In after years he exchanged into the 1st Royals, and was present at the taking of Bergen-op-Zoom, and at the battle of Vittoria.

The youthful Vignoles was placed under the care of his maternal grandfather, Dr. Charles Hutton, F.R.S., Royal Military Academy, Woolwich, by whom his natural talent and bent of mind for scientific pursuits were carefully developed. The ordinary subjects—the *ingenuæ artes*—of a sound and liberal education were acquired by him more completely than has been the case with many eminent members of the Profession of Engineering, which he afterwards adopted. But his early training in the theory and practice of mathematical calculation, under so eminent an instructor, gave him advantages of which he successfully availed himself in the preparation and working out of those large engineering schemes with which his name is associated. Mr. Vignoles has been heard to say that the computations required for the logarithmic tables published by his grandfather were (under the Doctor's supervision) chiefly undertaken by himself. The effects of such an apprenticeship were an unusual readiness and expertness in calculation, a profound acquaintance with the various systems of notation and measurement both English and foreign, and a singular power of lucid and methodical tabulation of results in all departments of practical science.

Mr. Vignoles made no pretension to be ranked in the list of the more advanced students of astronomy. The needful qualifications for such a position, early acquired experimental skill

and acquaintance with the higher branches of mathematical physics, he did not possess, nor did his active professional life leave him sufficient leisure for their cultivation. It may also be doubted whether his eager and impetuous disposition would at any time have made him a patient technical observer. Like every zealous lover of astronomy, however, Mr. Vignoles possessed an excellent astronomical telescope, which was in tolerably constant use in the grounds of his pleasant marine residence on the banks of Southampton Water.

On two memorable occasions Mr. Vignoles rendered distinguished services to astronomical science. The first was in connection with the now famous voyage to Spain of H.M.S. *Himalaya*, in July 1860, when he co-operated with the Astronomer Royal in organising the expedition, and more especially in providing in every possible way for the comfort of the party on their arrival at Bilbao. Not content with pointing out to the principal members the most favourable spots for observation through the district of the Cantabrian Pyrenees, and placing at their disposal the whole of his large engineering staff, Mr. Vignoles most hospitably received into his own house the Astronomer Royal and his family, M. Otto Struve, Dr. Whewell, late Master of Trinity College, Cambridge, and Lady Affleck, with other distinguished persons who had come from various parts to observe the total eclipse of the Sun on July 18. It should not be forgotten, moreover, that, previous to the sailing of the expedition, Mr. Vignoles had prepared and published, at his own expense, an elaborate map of the Sun's shadow-path over the northern coast of Spain, accompanied by copious topographical and general information of the greatest interest. This was supplemented by the Astronomer Royal's code of instructions, as an appendix, the little volume forming not only an indispensable handbook at the time, but a very pleasing memorial of what has since been considered a most gratifying and successful astronomical expedition.

The second occasion referred to was the occurrence of the total eclipse of the Sun, visible on the south coast of Europe, in December 1870. This expedition, whose head-quarters were to be the little port of Catania, in Sicily, was under the guidance of Mr. Lockyer; but the whole of the arrangements for the overland journey, *viâ* Munich and the Brenner Pass into Lombardy, and thence to Naples, were undertaken and most efficiently carried out by Mr. Vignoles, who was accompanied by his eldest son, Mr. Hutton Vignoles, C.E. It will be remembered that the astronomical party embarked in H.M.S. *Psyche*, which unfortunately struck on a sunken rock within a quarter of a mile of the Sicilian coast, and became a total wreck. Mr. Vignoles was by some years the senior of the party, but there was nothing of the timidity of age in his conduct on that critical occasion.

When the ship had struck, and the water was rapidly rising, Mr. Vignoles was found by his son in the cabin quietly putting

his papers together, and merely remarked, with the coolness of an old traveller, that the same thing had happened to him fifty years before, when his ship was stranded on the Island of Anticosti, at the mouth of the river St. Lawrence. After this untoward event, the smiles of Fortune did not favour the enterprise either by land or sea; but, if the party did not obtain the same success as had crowned previous attempts to observe solar eclipses within the last half-century, it, at any rate, deserved it. Mr. Vignoles and his son were stationed at a convent on the lower slopes of Etna. The preparations, however, were in great measure spoiled by the wretched weather, the Sun being veiled at the moment of obscuration by a blinding storm of sleet and rain, which effectually destroyed all chance of observation in the vicinity of Catania. Those stationed at Syracuse, farther to the south, were, however, more fortunate. The expedition returned home by Malta and the Mediterranean, the voyage being slow and tedious, and the non-arrival of some of the travellers at the expected time caused no little uneasiness to their friends in England.

Mr. Vignoles, till within a few days of his death, continued to take great interest in our Society, and his loss is much deplored. He was an intelligent and useful member, and one of the most regular attendants at our meetings during the long course of years which he has devoted to the general culture and advancement of practical science. He was elected a Fellow on January 9, 1829, and was for many years a member of our Council, and served occasionally as a Vice-President. He was also a Fellow of the Royal Society; and, in 1870, he was chosen to fill the important office of President of the Institution of Civil Engineers.

Of Mr. Vignoles' successful career as a civil engineer it may be sufficient to remark that he is to be credited with the construction of several of the principal railways and other engineering works in the British Isles and on the Continent. Among his railways may be mentioned the Midland Counties, the North Union, the Sheffield, Ashton, and Manchester, the little North-Western and the Dublin and Kingstown. Of the many foreign lines constructed under his supervision his name must continue to be associated, more especially by astronomers, as the engineer of the series of railways in the northern provinces of Spain.

Mr. Vignoles retained his activity of mind to the last. It was a great pleasure to him in his healthy old age to meet his astronomical friends at the monthly meetings of the Society, and on Friday, November 12, only a few days before his death, he attended the dinner of the Astronomical Club, when he appeared, however, to be scarcely in his general health, and retired earlier than usual. The next day he seemed quite himself again, with almost his normal stock of energy and spirits. He left town for his country residence at Hythe, Hants, on the same day; and that night he was seized with apoplexy, from the effects of which he gradually sank, and expired most peacefully in the evening

of the following Wednesday, November 17, 1875, in the eighty-third year of his age.

It may be interesting to add that Mr. Vignoles was a lineal descendant of the last Sieur de Prades, the first of this Huguenot family who came over as a refugee to these islands, and who died in Dublin in the year 1721. Of this exile he was the great grandson.

FRIEDRICH WILHELM AUGUST ARGELANDER* was born at Memel, in East Prussia, on the 22nd March, 1799. His father, who was of Finnish descent, was a merchant of that town, whilst his mother belonged to a German family. Their circumstances were such as enabled them to give their son a very careful training and education. Political events brought him into very early connection with historic names. After the battle of Jena the Prussian royal family left Berlin, and took up their abode for some time at Memel. The Crown Prince (afterwards King Frederick William IV.) resided at the house of Argelander's father, and formed there a strong and lasting friendship with the future Professor. Scarcely less intimate were his relations with Prince William, the present Emperor of Germany.

In due course young Argelander was sent to the gymnasium at Elbing, and in 1813 to the Collegium Fredericianum at Königsberg, from which, in April 1817, he proceeded to the University of that town. Although from the first a diligent student, he did not show any special taste for the science in which he was to become so famous until he was attracted thereto by the lectures of Bessel. This led him to request the latter to entrust him with some calculations for the Observatory. The *Fundamenta Astronomiæ* had then been just completed; but Bessel put into his hands the reduction of the observations of 67 stars observed by himself at Königsberg, and not previously observed since Bradley, and also the determination of the latitude of the Observatory from observations of circumpolar stars. The results of these labours were published in the 5th part of the Königsberg Observations, in which he introduced our late Associate to the scientific world as "one of his most distinguished pupils." Other calculations followed, and it was not long before Argelander took part also in the observations; the first of importance being that of the occultation of the *Pleiades* on the 29th of August 1820. Soon after that, on the 1st of October, he was regularly appointed as Bessel's assistant at the Observatory—the beginning of a career in which he enriched astronomy with results such as could only be obtained by a combination of uncommon genius with industrious zeal.

His first great labour was assisting Bessel in his survey of

* This notice is principally an abstract of that by Prof. Schönfeld in *Vierteljahrsschrift der Astronomischen Gesellschaft, Jahrgang* x, part 3.

the heavens by zone observations from 15° south to 45° north declination, in which the whole of the microscope-readings of the circle were made by Argelander, and there is abundant evidence in Bessel's writings how highly he appreciated the care and skill with which this assistance was rendered, as well as that in the subsequent reductions. These zone observations commenced in August 1821; earlier in that year Argelander was engaged in observations of stars at low altitude to be used in the formation of Bessel's refraction tables, and also in February and March in the observation of the Comet of 1821.

On the 1st of April 1822, Argelander took his degree as Doctor of Philosophy, after writing a paper, *De Observationibus Astronomicis a Flamsteedio institutis*. Later in the same year he published his able treatise, *Investigations on the Orbit of the Great Comet of* 1811, which made his name known through Europe. No other comet had been observed so extensively and over so long an interval of time; and after the most skilful and elaborate treatment of the observations, Argelander obtained an orbit of the period of 3,065·6 years (to be reduced in the next period to 2,888 years). His investigations were not without their influence upon Bessel's views on the repulsive force of comets' tails, which were further developed by him afterwards in his labours on Halley's Comet and in his controversy with Encke on the resisting medium in space.

On the death of Walbeck, the position of "Observator" at the Observatory at Abo became vacant, and application was made to Bessel to recommend to the authorities at St. Petersburg one of his pupils to supply it. Though exceedingly unwilling to lose him, Bessel named Argelander, and on April 28, 1823, the latter was appointed to the vacant office, and he left Königsberg in the following month, being succeeded there by Rosenberger. His journey to Finland was also his wedding trip, he having married at Königsberg, on the 2nd of May, Marie Sophie Charlotte Courtan; and with her he proceeded, through Dorpat (where he renewed his friendship, commenced in November 1820, with W. Struve) and St. Petersburg, to his new home in the country of his paternal ancestors.

The Observatory at Abo was then newly built and indeed not in all parts quite completed. Its equipment consisted, besides smaller instruments and clocks, of a 2-foot repetition-circle, a Fraunhofer's heliometer, and especially of a very good 8-foot transit instrument by the same artist. A meridian-circle by Ertel was provided in 1825 and was not ready for use until the spring of 1827. Before that time, therefore, the observations principally consisted of comets, and casual phenomena of different kinds. When in possession of the meridian-circle, Argelander undertook a more extended course of observations; and paid special attention in particular to the stars which were known or suspected to have a large proper motion.

In the years 1828 and 1829 Argelander completed Hour XXII. of the Berlin Academy Star-charts, which he had undertaken. It is one of the best of the series, and the accompanying catalogue forms one of the earliest examples of the accurate critical treatment of Bessel's and Lalande's zone observations. In the meantime great changes had occurred at Abo. On the 4th of September 1827 a fire broke out which laid the greatest part of the town in ashes, and destroyed all the buildings, library, &c. of the University. Although the Observatory was protected by its isolated position, and lost nothing but a large number of its impressions of printed observations, yet it was ultimately resolved to remove it as well as the University to the new capital at Helsingfors. Argelander was named Professor of Astronomy at the newly founded University there, and a new Observatory was ordered to be erected by the architect Engel, who had already built that at Abo. The plan was approved in 1830; but difficulties were found in laying the foundation on account of the nature of the soil. Finland was also visited about this time by the cholera, which travelled over Europe; and Argelander took an opportunity, after leaving Abo, of revisiting his old home in Prussia, and renewing his personal intercourse with Bessel. In August 1832 he took up his abode at Helsingfors, though the building of the Observatory was not yet finished. Observations commenced there in the following year; and in November 1834 the meridian-circle was ready for use, the new Observatory being also provided with a Munich refracter of 9ft. focal length and 6½-in. aperture, observations with which commenced in September 1835.

Argelander devoted himself principally to an extensive series of observations of the brighter circumpolar stars, and to an accurate investigation of his circle, especially of its flexure, by observations of stars and their reflected images. It was whilst at Helsingfors that he printed the Abo observations and catalogue, as well as his well-known treatise on the motion of the solar system deduced from his own observations of 390 stars, with results nearly similar to that formerly obtained by Sir William Herschel.

His stay at Helsingfors was not to be of long duration. The Prsusian Government had resolved in 1836 to establish an astronomical institution at Bonn, on the Rhine. In August of that year the Directorship of the Observatory was offered to Argelander; and early in 1837 he took up his residence in Bonn, and energetically commenced the ordering of the instruments and the preparations for the building of the Observatory. As a temporary *locale* in the meantime for observations, he selected a bastion of an ancient fortress close to the Rhine, where he carried on for some years his astronomical work with such means as he had—latitude determinations, comet observations, &c. He also made excellent use of his involuntary leisure in the formation of his "New Uranometry," or determination of the relative appa-

rent magnitudes of all the stars visible to the naked eye in Central Europe by direct comparison in the sky, as well as in the connected subject of the changes of magnitude of the variable stars. To the latter he continued to give a great deal of attention afterwards, especially in regard to those interesting stars, *Algol* and *S Cancri*.

Impatient at the slow progress of the Observatory (as he considered it) Argelander had a small temporary building erected, in which he could use (close to his Rhenish bastion) a 5-foot transit instrument by Ertel, of 4 inches aperture. Having provided this with a sector to determine differences of declination, he commenced extending Bessel's zone observations farther to the north, from 45° to 80° declination. Thus he made 26,424 observations of very nerly 22,000 stars; which, begun in May 1841, were essentially completed, with the aid of an assistant, in June 1843, some gaps being filled up in the subsequent spring.

At last, in the year 1845, the new Observatory was in a position to be used. Its principal instruments were a 3-foot meridian-circle by Pistor, with telescope of 6-foot focal length, and a heliometer by Merz. For some years cometary observations (a large number of which bodies appeared about that time) and observations of the small planets—the long series of discoveries of which had then just commenced—occupied much of the time of the new establishment. But in 1849 Argelander began a new series of zone observations of stars, this time going south from Bessel's limit, or from 15° to 31° south declination. Thus, by May 1852 he had made, in 200 zones, 23,250 observations of more than 17,000 stars. Every precaution was taken by comparison and by observation of known stars to secure the greatest accuracy possible for the results.

But even before the completion of these southern zones, Argelander had formed a plan for a much greater work to extend the knowledge of the starry heavens. Bessel had before conceived the idea of determining the places of all stars down to the ninth magnitude, but had abandoned it for the scheme of the Berlin Academy Star-charts, which, however, after the lapse of a quarter of a century, were unfinished, and, moreover, they embraced only a limited zone.

Early in 1852, therefore, Argelander resolved to commence that great *Durchmusterung*, or survey of all the stars of the northern hemisphere down to the ninth magnitude, and including a large number somewhat fainter than that, with which his name will be for ever associated. The whole number of stars recorded in these zones, between the north pole and 2° south declination, amounted to 324,198, and this gigantic labour, including the laying down of the charts and publication both of them and of the catalogues occupied Argelander and his assistants until the year 1863. They are too well known to astronomers to make any discussion of them necessary here. In the seventh volume of the *Bonn Observations*, published in 1869,

are some interesting investigations into the proper motions of 250 stars, which Argelander was led into by comparison of observations.

He always kept in view the desirability of obtaining accurate meridional observations of all stars down to the ninth magnitude, whose approximate positions are contained in the *Durchmusterung*. It was necessary, if this could be done, that the labour should be shared by different Observatories, and be prosecuted on a uniform system. Thus would a basis be afforded for a much larger number of accurate determinations and observations of every kind. In the year 1867 Argelander laid his plan before the German Astronomical Society, which was afterwards adopted, with trifling modifications. The Bonn Observatory was to undertake one zone of 10° in breadth of declination; but Argelander, now approaching his seventieth year, entrusted the details of the execution to his assistants, engaging himself in labours of smaller compass, such as investigations of stellar proper motion.

Argelander always took a lively interest in the progress of science generally, and also in the affairs of the University of Bonn, of which he was twice elected Rector. Many of the scientific societies of Europe and America made him one of their corresponding or honorary members, and he was chosen an Associate of our own on the 14th of January 1831, being also our medallist in the year 1863.

Until the summer of 1874 he had always enjoyed excellent health; but in August of that year he was attacked by a fever of the typhus kind, which visited the neighbourhood about that time. In the autumn he rallied, and was able to resume some of his labours. But the appearance of recovery was delusive; his strength failed more and more, and, retaining his interest in science almost to the last, a tranquil death early in the morning of February 17, 1875, terminated a life which had been so useful to astronomy. His wife (with whom he had been affectionately united for nearly fifty-two years), two sons, and one daughter, married to Professor Krüger, survive him. W. T. L.

Heinrich Louis D'Arrest was born at Berlin on the 12th of August 1822. His family is of French extraction, his ancestors having been among the Huguenot refugees who settled in Germany after the Revocation of the Edict of Nantes in 1685. In early life his tastes and inclination naturally led him to the study of mathematics, which was followed by its practical application in astronomical calculations and observation even while still a student at the University of Berlin. His name was first brought into notice outside his native city by an independent discovery of Mauvais' second Comet, which he detected on July 9, 1844, two days after it was first seen at Paris. At this time he had attained considerable skill as an observer, as is

shown by the fact that while informing Professor Encke of the discovery on the same night, he also furnished a position of the comet determined from a good series of observations. Although anticipated on this occasion, he had the good fortune to detect another comet on December 28 of the same year. Continuing his cometary investigations, D'Arrest communicated to Professor Schumacher, in September 1845, a very careful discussion of the observations of Colla's Comet, which had been first detected by the naked eye in the first week of the preceding June. Soon after this D'Arrest was appointed an assistant at the Observatory of Berlin, then under the direction of Professor Encke. In 1848 he accepted the office of Observer at the Leipzig Observatory, and shortly afterwards that of Professor of Mathematics and Astronomy in the University. Here he remained till 1857, when he received the appointment of Director of the new Observatory in connection with the University of Copenhagen, in which his first duty was the superintendence of the construction and instrumental equipment of the new establishment.

During D'Arrest's residence at Leipzig, he discovered the interesting periodical comet which bears his name, new osculating elements of which have recently been computed by M. Leveau, referred to in a subsequent section of this Report. He also during this time communicated to the *Astronomische Nachrichten* and the *Monthly Notices* numerous elements and ephemerides of the minor planets and comets calculated by himself, and in 1851 he published a valuable paper on the general system of the minor planets. Soon after his appointment to the Leipzig Observatory, he commenced his important series of observations of the positions of the Nebulæ. These Leipzig observations appeared, as a first instalment of nebulæ results, in his work published in 1856, entitled, *Resultate aus Beobachtungen der Nebelflecken und Sternhaufen.* The merits of this, and of his still more important work on the observation of the nebulæ, made subsequently at the Observatory of Copenhagen, entitled *Siderum Nebulosorum Observationes Havnienses*, were fully considered by our President in his address delivered on presenting the Gold Medal of the Society to our late Associate at the last anniversary; and, for this reason, there is no need for us to dwell upon them here, except to remark that, had these volumes been the only production of Professor D'Arrest, they would alone be a sufficient memorial of the observational energy displayed by him both at Leipzig and Copenhagen. From the beginning to the end of his career he may truly be classed as one of our principal observing astronomers; and in proof of this, a glance at his numerous contributions on various astronomical subjects, to be found in the *Astronomische Nachrichten*, and in other scientific serials, is a sufficient testimony. This activity and devotion to astronomical research continued to the end of his life, for even in the number of the *Astronomische Nach-*

richten which records his death, some valuable remarks by him on some newly discovered objects exhibiting Star-spectra similar to Secchi's third and fourth types are also inserted. The Royal Society's Scientific Catalogue contains a list of 104 separate papers by D'Arrest published before the end of 1863.

D'Arrest was the discoverer of one minor planet, *Freia*, in addition to several comets. Before the systematic observation of the nebulæ occupied so much of his time, he did good service to astronomy as the calculator of the elements of the orbits of the comets of Colla, Biela, Brorsen (second), Hind (second), Colla (second), Miss Mitchell, and others. He also published elements of the orbits of various planets, among others, of *Astræa*, *Iris*, *Flora*, and *Hygeia*, soon after their discovery. He was indeed at this time one of the most energetic of the many young German astronomers who undertook the calculation of elements and ephemerides of newly discovered planets and comets, a necessary and important branch of our science, which is still so successfully cultivated at the present time in Germany under the able supervision of Dr. Foerster and Dr. Tietjen.

As a conscientious and skilful teacher, D'Arrest was popular among those who came to him for instruction. Whenever he detected real abilities in his pupils, with a never-failing energy he afterwards helped and assisted them in their studies, not forgetting at the same time that he was himself still a student, and that when in his thirty-sixth year he commenced the study of a foreign language which he perfectly mastered. He was indeed naturally endowed with superior abilities, which he constantly and progressively developed by the most diligent study. His knowledge of astronomical literature was very extensive, and he was also a good geometer, which is clearly manifested in several of his minor works. His intercourse with his father-in-law, the celebrated geometer, Möbius, of Leipzig, may possibly have influenced him in this branch of mathematics. But the inclinations and talents of D'Arrest were more particularly directed to a class of scientific research in which conjectural reasoning was the main point of investigation, as well as to those observations in which great technical knowledge was not so much required as the power of observing phenomena properly and correctly, and afterwards giving an accurate interpretation of what has been seen. Acting in this spirit, D'Arrest employed much of his time in investigating the nature of the composition of the heavenly bodies, and particularly of the nebulæ; and this subject had of late years been the main study and object of his life, leading him to undertake a series of spectroscopic observations of the nebulæ, a discussion of which, giving the results obtained, was published at Copenhagen in 1872.

Professor D'Arrest, during the latter years of his life, was subject to an occasional nervous prostration, caused probably

by the gradual progress of the organic disease which ultimately terminated his life. It has been remarked that he suffered from a hypochondriasis which increased year after year. His death took place suddenly, from disease of the heart, on June 14, 1875, having scarcely completed the fifty-third year of his age.

D'Arrest was a member of several scientific societies, including the Societies of Sciences of Denmark and Sweden, and the Academies of Sciences of St. Petersburg and Munich. He was elected an Associate of the Royal Astronomical Society on May 12, 1848. He was also a Knight of the Danish Order of the Dannebrog.

In addition to the numerous papers contributed to astronomical science inserted in the *Astronomische Nachrichten* and *Monthly Notices*, Professor D'Arrest was also the author of the following more elaborate works:—

Ueber das System der Kleinen Planeten Zwischen Mars und Jupiter. 1851.

Resultate aus Beobachtungen der Nebelflecken und Sternhaufen. 1856.

Instrumentum magnum aequatorium in Specula Universitatis Havnienses nuper erectum. 1861.

Teleskopisk Undersögelse af Egnen omkring det Sted pad Himlen, hoor Tychos nye Stjerne har vist sig 1572–1574. 1864.

Siderum Nebulosorum Observationes Havnienses. 1867.

Undersögelse over de nebulose Stjerner i Henseende til deres spektralanalytiske Egenskaber. 1872.

Claude Louis Mathieu was born at Macon, Saône-et-Loire, on November 25, 1783, in humble circumstances. His father, a joiner by trade, intended his son to follow his own occupation; but desiring to make young Mathieu a superior workman, he sent him to an elementary school in his native town, where he received the rudiments of his education, and where he was able to attend a gratuitous course of instruction in drawing. He was soon noted for his aptitude and general assiduity in his studies; and it was here that he first acquired a taste for the study of mathematics, but without the guidance of a teacher. But finding himself frequently in the presence of serious difficulties, he solicited the advice of the learned and venerable Abbé Sigorgne, who became much interested in the young student. The difficulties were great, but not insurmountable, and he was encouraged by reading daily in the preface of Lacroix's "Algebra" the precept of D'Alembert:—"Allez en avant, et la fin vous viendra." Having heard of the École Polytechnique, all his efforts were at once directed to become a student in that celebrated training-school. He left Macon in 1801, and arrived in Paris almost without resources. He was glad to accept the offer of a lodging in a small room under the Observatory of

Delambre when he attended a gratuitous course of study at the "École centrale des quatre nations," where he eventually obtained the first prize for mathematics. In 1803 he was admitted a pupil at the École Polytechnique, where he remained two years, leaving it in 1805 with the title of "Élève ingénieur des ponts et chaussées."

Five years after leaving his native town, through an acquaintance formed with Arago at the École Polytechnique, M. Mathieu was appointed to the temporary charge of the Paris Observatory during the absence of his friend in Spain, while engaged with Biot on an expedition for the continuation of the observed arc of meridian as far as the Balearic Islands. In 1808 Mathieu himself was associated with Biot in making a series of pendulum observations at different stations on the French meridian, for which he obtained in 1809, and again in 1812, the astronomical prize founded by Lalande. In 1807 he received the appointment of Titular Secretary to the Paris Observatory.

Mathieu was elected in 1817 a member of the Académie des Sciences, succeeding Messier in the section of Astronomy, and at the same time he was appointed a member of the Bureau des Longitudes. Subsequently he became a teacher of geodesy, &c. at the École Polytechnique; in 1829, professor of analysis; and finally, examiner de sortie in the same school, where his name is still honourably remembered as a clear, methodical, and conscientious professor.

Although Mathieu had devoted so large a portion of his life to astronomical pursuits as the colleague of Arago, at the Paris Observatory, by his numerous observations and researches on the figure of the Earth, on refraction, on the obliquity of the ecliptic, on the parallax of the fixed stars, &c., and when on account of his age he might reasonably have claimed some relaxation from active work, he accepted, after the death of Arago, the heavy charge of superintending the calculations and the annual publication of the *Connaissance des Temps* and the *Annuaire* of the Bureau des Longitudes. Latterly, however, his duties were confined chiefly to the superintendence of the *Annuaire*, and it is to him that we have been indebted for those portions relating to astronomy, the physics of the globe, and statistics, the value of which for reference has been so highly appreciated even out of France. M. Mathieu continued this supervision to the last, and it was only a few weeks before his death, with a failing hand, he examined the concluding proof-sheets of the last volume of the *Annuaire*, which had been so long the principal object of his solicitude.

On the death of Delambre, in 1822, a most important part of his *l'Histoire de l'Astronomie au XVIII^e siècle* was left unfinished. This distinguished astronomer left the completion and publication of the work as a legacy to Mathieu; and, in consequence, it appeared in 1827, enriched by him with an historical preface, a

large number of important notes, and a very exhaustive analytical table of contents.

M. Mathieu served on several important Commissions. Among those relating to science may be mentioned the joint French and English Commission appointed to make a geodetical connection between the English and French coasts by means of a series of triangles carried across the English Channel; the Lighthouse Commission, of which he was one of the leading members; and the Metric Commission. In 1867 he was chosen President of the International Coinage Commission, an honour repeated in 1872, when he was the President of the International Metric Commission. He also served on the jury at the London International Exhibitions of 1851 and 1862, and at the Paris International Exhibition of 1855. In 1829 he was made a Chevalier, in 1855 an Officer, and in 1863 a Commander of the Legion of Honour. He was elected an Associate of this Society on May 12, 1848.

Following the example of his friend and relative, Arago, Mathieu during the period of his middle life divided his time between science and politics. It is not necessary, however, in this place to enter into much detail respecting his political career. It will be sufficient to remark that he represented his native town in the Chamber of Deputies, without interruption, from 1835 to 1848. After the Revolution of February 1848 the Department of Saône-et-Loire elected him to the Constituent Assembly by 127,052 votes out of 132,000. In 1849 he retired from the Assembly, after which his time and energy were chiefly devoted to the promotion of science; but he retained a great interest in political events to the last. During the siege and the more terrible scenes of the Commune he expressed no desire to leave Paris, and his example encouraged his friends around him during this trying time.

M. Mathieu married the sister of Arago, and we have already noticed that the subsequent careers of the two astronomers were very much in common, following the same tastes both scientific and political. His daughter became the wife of our late Associate, M. Laugier, whose death the Council had to deplore in a recent Annual Report. The patriarchal age to which M. Mathieu reached shows that he was possessed of a strong and healthy constitution, which only succumbed at last to a gradual decay of nature. His death occurred in the first week of March 1875, in the ninety-third year of his age, and at his funeral, on March 8, discourses were pronounced over his grave by MM. Faye, Loewy, Resal, and Guillemaut.

During the preparations for the Exhibition of 1855, the writer of this notice, while residing in Paris in connection with the Exhibition, had the opportunity of associating with the principal Paris astronomers, and he has retained many pleasing reminiscences of the urbanity and kindness of the three astronomers, Mathieu, Delaunay, and Laugier, who resided together in the

same house in the Rue Notre Dame des Champs, all of whom were ever ready to assist him by their counsel, and in other ways. It has since become his melancholy duty to record briefly, in the obituary section of our Annual Reports, the eminent services to science of each of these three distinguished men.

The published works of M. Mathieu are not numerous. In addition to his reports on scientific subjects and other papers alluded to in this notice, the following memoirs have appeared in the Appendices to the *Connaissance des Temps*:—

1. *Sur les expériences du Pendule, faites par les navigateurs Espagnols en différents points du globe.* 1816.

2. *Résultats des expériences faites avec des pendules de comparaison aux îles Malouines et à la Nouvelle Hollande.* 1826.

3. *Rapport sur un mémoire de M. Puissant sur la détermination de la figure de la terre par les mesures géodésiques et astronomiques.* 1829.

4. *Note relative au mémoire de M. Bessel, et aux catalogues des 36 étoiles fondamentales.* 1829.

Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council.

Royal Observatory, Greenwich.

In addition to the usual observations with the Transit-circle and Altazimuth, a series of micrometric measures of *Saturn's* satellites has been made with the Great Equatoreal, Mr. Marth's ephemeris having been found of great use in the identification of these objects. The measures were much interrupted by bad weather, but fairly complete sets have been obtained on nineteen days, and the observations are ready for communication to the Society. The results of the series of differences of R.A. and N.P.D. of cusps made during the Solar Eclipse of last September have been already published in the *Monthly Notices*.

The Great Equatoreal has also been used (in addition to the Sheepshanks Equatoreal and Altazimuth) for occultations of stars by the Moon, and for phenomena of *Jupiter's* satellites; but the chief work to which this instrument has been devoted has been the spectroscopic examination of the Sun and of stars. The results of the latter are given in the *Monthly Notices* for November, and the agreement with Dr. Huggins' observations is most satisfactory, when the measures which are known to have been made under bad circumstances are rejected. With a single exception, the two sets of observations agree as to the direction of motion of all the stars (12 in number) common to both, and for those that have been well observed in both series the numerical values differ generally by less than 10 miles a second, which is quite as close an agreement as could be expected from the nature of the case. The star η *Ursæ Majoris* offers the only instance of discordance, and it is to be remarked that Dr. Huggins does not express himself with any confidence as to his observation of this star. The Solar prominences have been mapped on 31 days with the Observatory Spectroscope, and the breadths of the Fraunhofer lines have been measured with the powerful Spectroscope which Mr. Spottiswoode kindly lent to the Observatory. All these observations have been much interrupted by the exceptionally bad weather of the past year; and also to a less degree by the alterations which were found necessary in the Observatory Spectroscope. As bearing on the constitution of comets, a careful comparison has been made of the spectra of the various carbon compounds, the two spectra to be compared being placed side by side in the same field, and the relative position, brightness, and degree of shading off of the bands noted. It is proposed to repeat these observations with carefully prepared vacuum tubes.

With the Photo-heliograph 346 photographs have been selected from those taken on 166 days in 1875; an unusually small number, though every opportunity, on Sundays as well as week days, was taken advantage of. Since last September the Photo-heliograph returned from the Transit of *Venus* Expedition to New Zealand has been used for this work. Many of the photographs are entirely without spots, and a similar absence of prominences has been remarked with the Spectroscope. The areas of the spots and faculæ have been measured and completely reduced to the end of 1874, and the results are in the printer's hands for insertion in the forthcoming volume for 1874.

The weather was generally unfavourable for the observation of the August and November meteors: the night of November 14 was, however, fine, and a strict watch was maintained throughout; but owing to the brightness of the Moon, only large meteors could be seen. One meteor was recorded on November 13, and 25 on November 14. Some of those observed on the latter night did not belong to the stream of the *Leonids*.

From a change made in the position of the division used for the Nadir observation in the field of view of the Transit-circle Microscopes, it appeared that the correction to the Nadir observation depended on the part of the micrometer screws used, its value having changed from $-0''.7$ to $+0''.6$. This led to the supposition that the screws had worn considerably, an inference which was confirmed by a determination of the values of successive revolutions (by means of the South Collimator) as well as by Nadir observations taken with the same division in different parts of the field; at the same time the telescope-micrometer screw was found to be free from sensible error. To test this important point still further, the four supplementary microscopes used for examining the division-errors were mounted, and the results given by them compared with those given by the six ordinary microscopes for every observation during a period of two months. A table of corrections to circle readings for every revolution and tenth of the six ordinary micrometers has in this way been formed, and these, which range from $-1''.07$ to $+0''.75$, are being applied to all observations of stars since the completion of the second Seven-year Catalogue in 1867. The investigations of R—D correction and of co-latitude will be slightly affected, but the determinations of flexure will be free from sensible error. The old screws have now been replaced by new ones, made with very great care, which are now being compared with those of the supplementary microscopes. The adoption of a correction to the Nadir observations for some years past makes the adopted Zenith-points free from systematic error, as the observations of stars by reflection are on the whole distributed equally over the range of the micrometer screws.

Among the instrumental changes may be mentioned the alteration of the Altazimuth Collimator, which is now horizontal, and therefore gives the collimation error independently of the observation of a high star.

Various alterations have been made in the Spectroscope, chiefly with a view of improving the definition; but though a viewing telescope with right-angled reflecting prism was mounted as in the ordinary form of solar spectroscope, matters appeared to be worse instead of better, and it was ultimately found that all the trouble arose from the deviation through the first half prism (compound) being 5° greater than it should have been; in consequence of which the pencil did not fall fairly on the train of prisms, and there was a great deal of false light reflected from the base of the prisms. It can only be conjectured that some mistake had been made in the density of the flint glass, and Mr. Hilger is now correcting this by increasing the angle of the crown prism. From trials that have been made, there is no doubt that the definition will be very fine when this defect is corrected. For more accurate measure of lines in stellar spectra, Mr. Hilger has applied a new form of bright-line micrometer which has given excellent results, and other small additions (mentioned in the *Monthly Notices* for last November) have been made as suggested by experience. It is in contemplation to commence a series of measures of the breadth of the lines of hydrogen and other elements at different pressures, and with this object in view a Sprengel pump on Mr. Crookes' model has been supplied by Mr. Hicks.

Preparations have been made for a Nine-year Catalogue of all stars observed from 1868 to 1876, the special feature of which will be the circumpolar stars, which have been observed assiduously since 1872. It is hoped that there will be very few stars in this catalogue which have not been observed at least three times both in R.A. and N.P.D.

The reductions are in a very forward state, and the printing of the volume for 1874 is well advanced; that for 1873 has been distributed.

The Transit of *Venus* reductions are proceeding vigorously under Capt. Tupman's immediate superintendence, and great progress has been made by Mr. Burton in the measurement of the photographs. A more detailed account is given under the head of "Reduction of the Observations of the Transit of *Venus*."

Radcliffe Observatory, Oxford.

No important change having taken place since the last Report in the organisation or the subjects of observation of this Observatory, no details will be necessary.

Referring to the Report of the Radcliffe Observer to the Board of Trustees, delivered on the 29th of June 1875, we find that the volume of *Observations* for 1872 was completed and circulated at the beginning of February 1875, and that the volume contained a catalogue of 1,323 stars, 89 observations of

the Sun, 48 of the Moon, 13 of *Mercury*, and 16 of *Venus*; a catalogue of 20 double stars; 12 observations of occultations of stars by the Moon, thoroughly reduced; and, finally, a considerable list of shooting-stars.

At the present time the succeeding volume for 1873 is quite finished and ready for distribution. This volume contains a catalogue of 1,496 stars, 95 observations of the Sun, 55 of the Moon, 20 of *Mercury*, 33 of *Venus*, 24 of *Mars*, and 18 of *Saturn*; a catalogue of 17 double stars, many of them repeatedly observed; 11 occultations of stars by the Moon; a large number of observed phenomena of *Jupiter's* satellites; and, finally, a considerable list of observations of meteors and shooting-stars. The meteorological portion of the volume contains the usual amount of information in the usual shape.

The continued activity of the Observatory is shown not only by the early publication of the volume for 1873, but by the great progress which has been made with the reductions during the past year. Those of 1874 of every sort are complete, and two half-sheets of the transits are printed. The separate results both in R.A. and N.P.D. have been written out, and the Catalogue has been formed and the results entered into it as far as is practicable.

For the year 1875 the reductions of the Right Ascensions and North Polar Distances are nearly complete, and the occultations and other observations of a miscellaneous character have been reduced.

There are still some arrears of the meteorological reductions beyond what is desirable, but it will be now possible to devote a good deal of time to them, and it is hoped that we shall shortly have to report that the reductions have in every department kept pace with the observations.

Oxford University Observatory.

This Observatory was so fully described in a communication inserted in the *Monthly Notices* of November last, that no further remarks on the subject are required.

On the 2nd of December last the Board of Visitors met at the Observatory for the first time, when the Vice-Chancellor, the Astronomer Royal, and other members of the Board were present. The scheme of observations connected with astronomical physics, proposed by Professor Pritchard, was laid before the Board and approved of.

It is proposed to include in the routine of the Observatory work:—1. The observation of any new comets which may appear; the calculation of their orbits, and the record of their spectra and of other physical circumstances, including the radiants of their possible star showers. 2. The re-observation of such

binary stars as afford the promise of calculable orbits; their orbits, their spectra, and other physical circumstances will be obtained and recorded. 3. A series of lunar photographs is to be taken with the De La Rue Reflector, with the view of ascertaining the existence of any possible physical libration. 4. It is proposed to give immediate attention to any celestial phenomena of especial interest which may occur and fall within the optical means of the Observatory.

The lunar photographs have already commenced. Up to the present time observations of six of the satellites of *Saturn* have been obtained, more or less successfully, during thirty-one nights. The faint satellite *Mimas* was seen on one occasion, and its place estimated. The re-observation of about thirty of the stars in Sir John Herschel's *Catalogue of Double Stars* has been completed, some doubts having been thrown upon their accuracy or identity as they appear in Sir John's compilation. The results will shortly be communicated to the Society, as will also the observations of the satellites of *Saturn*.

Cambridge Observatory.

In a year unusually unfavourable for observation, and with an unavoidable interruption to the work in May and June, we have been able to register 3,302 observations of small stars, and 511 of fundamental stars, with all the requisite observations for level, collimation, and Nadir-point.

All these have been entered in the Reduction Books and the means taken. The Right Ascension observations of fundamental stars are completely reduced up to the end of 1874. The observations for level, collimation, and Nadir-point are reduced up to November 24, 1875. The constants for obtaining the apparent Right Ascensions and North Polar Distances of the Zone stars are completely calculated to the end of 1874, and partially to the end of 1875. In the course of these reductions it has been found that there is still a slight discrepancy in the Nadir-point. When this is found by turning the instrument through the South horizon it is about $0''.16$ greater than when the instrument has been turned through the North horizon.

The Right Ascensions and North Polar Distances for 1867 are printed, and the *Catalogue of Mean Right Ascensions of the Fundamental Stars* for the same year is in the press.

The Meteorological Observations are daily communicated to the Central Meteorological Office in London.

The Observatory, Dunsink, Co. Dublin.

During the year 1875 the Transit-circle has been in regular use. Considerable progress has been made in the exact determination of the places of the objects in Schjellerup's new *Catalogue of Red Stars.* A number of other stars have been observed for various reasons. A few minor planets have been included in the working list as occasion offered. Considerable progress has been made with the reductions, extensive tables for facilitating which have been constructed in great part by Dr. Brünnow.

Dr. Brünnow had completed an examination of the Transit-circle with the exception of circle B. The systematic errors of the divisions of circle A as determined by him do not, for four microscopes, in any case exceed 0″·6, and even this quantity is almost entirely eliminated by the application of a correction of the formula, $a \sin 2\omega$. The periodic errors of the microscope-screws were originally rather large; but a re-examination by Dr. Copeland last autumn shows that, although still retaining the same general character, the coefficients have become much smaller. A new sidereal clock, by E. Dent & Co., with zinc-steel compensation, has been erected.

It is Dr. Ball's intention to resume the observations for Annual Parallax with the South Equatoreal. In fact, a commencement has been already made.

Royal Observatory, Edinburgh.

Professor Smyth reports that during the past year his time and that of his assistants, Mr. Wallace and Mr. Heath, have been employed on the following work:—

1. The daily exhibition of the correct time by means of electric time-ball, time-gun, and controlled clocks over Edinburgh and its neighbourhood.

2. The computations of the bi-diurnal observations made at 55 of the stations of the Scottish Meteorological Society, and their condensation for the Reports printed monthly and quarterly of the Registrar-General of Births, Deaths, &c., in Scotland.

3. Twelve months' hard work for all hands at the Star-catalogue computations from 1830 to 1870.

4. Reports, as called for, to H.M. Office of Works on the state and quality of the several portions of the New Equatoreal, which is still unpassed out of the hands of that department. The most important question therein was concerning the figure of the large silver-on-glass speculum, and in that the Astronomer, as he is most happy to mention, had the able assistance of the Rev. H. Cooper Key, of Hereford, who kindly came to Edinburgh at his own expense for that sole purpose.

5. Further particulars of the present state of the Observatory and its works are contained in a detailed Report by the Astronomer, presented last May to the Board of Visitors, Edinburgh, and since then printed and generally distributed. Professor Smyth remarks that the total expenditure of the Observatory during the past year, including salaries, instrumental repairs, and office expenses, amounted to £1,070.

Glasgow Observatory.

The astronomical operations at the Glasgow Observatory during the past year have consisted mainly in the reduction to the commencement of 1870 of the zenith distances of small stars which have been accumulating at the establishment since the year 1860. The work is now considerably advanced; and it is intended soon to prosecute the observations with the Transit-circle more actively, with the view of procuring the materials which may be required for the final completion of a catalogue of stars. The usual operations for transmitting Greenwich time to the city and port of Glasgow have been conducted without interruption as in former years. A similar remark applies to the meteorological observations obtainable with self-registering instruments, which are prosecuted at the Observatory in connection with the Meteorological Committee of the Royal Society, and also to the ordinary meteorological work of the establishment.

Kew Observatory.

The photoheliograph transferred to Greenwich in February 1873, having been returned by the Astronomer Royal, has been replaced in the dome of the Observatory.

The re-examination of the measurements of the Kew Sun-pictures, taken during the ten years 1862–1871, has been steadily carried on, the expense attendant on the same being borne by Mr. De La Rue. The discussion of the photograms obtained of the 15-ft. scale, erected for the purpose of determining the optical distortion, has been completed; and tables for determining the angle of position of the Sun's axis and the latitude and longitude of the Earth referred to the Sun's equator, for use in the reduction of the solar photograms, have been printed for, and distributed by Mr. De La Rue.

Experiments were carried on throughout the greater part of last year with the Photometer designed by Prof. H. Roscoe for

measuring the total intensity of daylight, and the registering Sun-dial invented by Mr. Campbell, which was in operation for several years at Whitehall, has been set in action on the roof of the Observatory, together with a modified form of the instrument, by which a daily record is obtained of the Sun's heating power.

Certain apparatus used for the swinging of invariable pendulums, which was in store at the Observatory, having been repaired at the expense of the Admiralty, two officers attached to the Arctic Expedition attended at Kew for some weeks, and after going through a course of instruction in the use of the apparatus and the method of observing pendulum vibrations, made a set of observations, which are recorded for the purpose of making Kew a base station. The apparatus was then dismounted, packed, and shipped on board the "Discovery."

The usual work of the Observatory in the Magnetical and Meteorological departments has been carried on throughout the year without intermission, and great activity has prevailed in the Verification of Instruments department.

Liverpool Observatory, Bidston, Birkenhead.

The work at this Observatory has for several years past been largely devoted to the testing of chronometers for weekly periods, in each of the three temperatures, 55°, 70°, and 85°, and no change has been made during the past year with the exception of one occasion, on which a large number of chronometers were exposed for a special purpose during one week to a temperature of 95°.

On comparing results obtained some years ago with those of a more recent date, there is a marked improvement in the primary compensation for temperature correction as regards its adaptation to an ordinary sea voyage. A large proportion of the new chronometers tested at this Observatory during the past year have been found to have their maximum gaining rates in temperatures ranging between 65° and 75° of Fahrenheit, so that the correction due to imperfect thermal adjustment, between about 60° and 80°, has often been found to be very small; at 40° from the maximum gaining rate the average daily loss is, however, nearly five seconds. It would be a great boon to navigation if all chronometers were tested for the necessary data, and the rates calculated and supplied to the mariner for every degree of Fahrenheit from 55° to 95°. The expenses attendant on so giving the rates might be recouped by a charge of about £1 for each chronometer, and for this small sum the value of the instrument for finding the longitude at sea would be enhanced to an extent scarcely credible to the inexperienced in these matters.

Temple Observatory, Rugby School.

The past year has been chiefly occupied in the measurements of double stars with the Alvan Clark Refractor. The number of stars measured is 303, a somewhat smaller number than last year. The decrease is due, partly to the exceptionally small number of nights sufficiently fine to be utilised for this purpose, and partly to the fact that Mr. Wilson has been prevented by ill-health from taking part in the work. All the measures have been taken by Mr. Seabroke and Mr. Percy Smith.

The spectroscope carried on the 12-inch Reflector has been used for mapping the positions and forms of solar prominences, and for other observations of the Sun. The number and size of the prominences during this year having been very small compared with those of previous years, it was deemed expedient to substitute for the ring slit (which shows one-half of the chromosphere in the field of view at one time) a slit the jaws of which were turned to a segment of a circle, on which about 20° of the Sun's limb exactly fitted. This was used in the place of the ordinary slit, and of course a larger image of the chromosphere seen. Drawings were made on 35 days.

Early in the year an astronomical clock by Cooke was purchased from Mr. E. Crossley. It is placed in Mr. Wilson's house, and regulates, by an electric current, an ordinary eight-day clock in the Observatory.

A few drawings of *Jupiter* have been made by members of the School, who have also assisted to some extent in other work.

Stonyhurst Observatory.

The reduction of the magnetic records of past years has occupied most of the time that could be spared, during the last twelve months, from the ordinary routine work of the Observatory.

The absence of the Director on the Transit of *Venus* Expedition to Kerguelen Island has interfered somewhat with astronomical work; but the regular observation of *Jupiter's* satellites, of lunar occultations, and of the November meteors has not been interrupted.

Mr. Barclay's Observatory, Leyton, Essex.

During the past year attention has been given to the perfecting of the Leyton double-star catalogue. All known and suspected binary systems are kept in the working catalogue.

Sir J. Herschel, shortly before his death, was kind enough to

send Mr. Barclay a list of stars that he thought worthy of particular attention. Some of these have been observed and will form part of the next volume of *Observations*. The weather during the past twelve months has, here, been most unfavourable for delicate measures.

The instruments remain in the same condition as last year. Several gentlemen who are building observatories have visited Leyton for the purpose of inspecting the dome, the arrangements of which (described in Vol. I. *Leyton Observations*) continue to give perfect satisfaction.

Colonel Cooper's Observatory, Markree.

Dr. Doberck, who has charge of this Observatory, reports that the instruments have not been employed since the death of the late Mr. Cooper. On his appointment he found the instruments decaying from neglect, the steel pivots corroded with rust, the micrometers and clock-work covered with dust, and the building in such a dilapidated condition that the rain penetrated through the roof. The Refractor, exposed during forty years in the open air to the winds and rain of Connaught, was of course in the worst condition. It has now been restored as far as practicable. The old clock-work still drives it as well as could reasonably be expected. On account of the delay caused by the workmen, the repairs of the instruments were carried on so slowly that Dr. Doberck was only able to commence observations in December. He has measured several double stars with the Refractor, and also observed some planets with the Meridian-circle. A cheap Chronograph has been lately added to the instruments.

Since the latter part of 1874 the Observatory has been furnished with a complete set of meteorological instruments, and observations have been made daily at 9 A.M. and 9 P.M., according to the regulations of the Meteorological Office. These observations have been made by Miss A. Doberck. The requisite examination of the instruments before they could be made available for the observations has necessarily occupied a large portion of Dr. Doberck's time during the year.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

During the year 1875 the measurement of binary stars and the observation of the phenomena of *Jupiter's* satellites have been, as in previous years, the chief work of the Observatory. Owing to bad weather the number of observations has been unusually small; but much time has been spent in compiling a

return, all his available time has been devoted to a systematic examination of this work, and about 8 hours are prepared for press, and the preparation of the remainder is far advanced.

The want of systematic examination in some of the earlier stages, and the number of single observations of stars, has rendered the work of final examination much heavier than had been anticipated. The catalogue will contain positions of more than 2,000 stars; but, from the use of two instruments, the Transit and the Mural-circle, unavoidable at the time, a large number of the observations are not complete in both elements.

A Photo-heliograph has been secured for the Observatory, and has quite recently reached the Cape. The arrangements for the erection of the necessary buildings are in progress, but the chemicals and chemical apparatus have not yet been received. It is hoped that, without interfering with the regular work of the Observatory, two photographs of the Sun may be obtained every clear day. These, with the photographs secured in England, should be sufficient to afford a daily record of the Sun's disk. Should, however, the work be taken up systematically at other southern stations, then, to avoid unnecessary duplication of the work, the Cape instrument would only be employed occasionally to trace changes in groups of spots, or upon other special inquiries.

The large Spectroscope ordered for this Observatory some years ago, and which was completed just as the Astronomer left England, has not, from some unaccountable delay, yet reached the Cape.

The zeal displayed by the assistants in clearing off the large zone of stars 145° to 155° N.P.D. during the year needs a word of warm commendation.

Adelaide Observatory.

Mr. Todd mentions in his Report to the Government of South Australia, dated September 24, 1875, that the astronomical work of the Observatory during the preceding year has been confined principally to the meridional observations of transits of clock-stars for the determination of local mean time, and to occasional extra-meridional observations made with the 8-inch Equatoreal by Cooke mounted in December 1874. Owing to the extremely moderate instrumental equipment of the Observatory, which, until the mounting of the new Equatoreal, consisted only of a small Transit instrument lent by the Victorian Government and an old Altazimuth, astronomical observations have necessarily been very limited. Mr. Todd, however, is very desirous to make the Observatory in future practically useful to the Colony as an educational establishment in connection with the University and higher-class schools. In making

this proposal to the authorities, he has no wish to curtail the usual regular work; but he thinks that it might also be easily extended, and thus render valuable aid in those branches of astronomical research which do not involve continuous observation or heavy computation, especially of solar and stellar spectroscopy, Sun-spots, double stars, and observations of the phenomena of *Jupiter's* satellites.

During the late Transit of *Venus* a large number of micrometric measurements were made; and also a series of differential observations in R.A. and N.P.D. were made of *Mars* during the recent opposition. The time-ball has been dropped by a galvanic current from the Observatory at 1 P.M. daily, except on Sundays, since the beginning of August. This daily exhibition of mean time at Adelaide is regarded as a great boon by those connected with the shipping; and its usefulness is much increased by the time-ball being visible from the port, and outside at the anchorage in the gulf.

An excellent six-prism Universal Automatic Spectroscope, by Browning, adapted for telescope or table work, and a large induction coil, by Siemens, have been provided. Mr. Todd is anxious now to procure a Transit-circle with an object-glass of 5-in. aperture, and a 3-ft. or 3-ft. 6-in. circle, so that meridional observations may be made in both elements. The transit-clock is not a good one, and it is proposed to substitute a new clock for it, now that the responsibility of dropping the time-ball devolves upon the Observatory. The new 8-inch Equatoreal is favourably reported upon, the definition being good, the Moon, *Jupiter*, and *Saturn* often bearing the highest power, 660. Mr. Todd, however, remarks that there is more blue light than he likes, which is especially noticeable in the case of *Mars*.

The meteorological branch of the Observatory continues its regular work, the observations of the usual elements being made five times each day. Similar but less complete observations are made at several of the telegraph offices, and at most of the lighthouses, and forwarded periodically to the Observatory. Rain-gauges have been supplied to about seventy stations in the Colony, which send in their records monthly.

Melbourne Observatory.

Referring to the Report of Mr. White, the acting Government Astronomer during the absence of Mr. Ellery in Europe, presented to the Board of Visitors in June last, we gather that the preceding year had been one of great activity in all branches of astronomy. Mr. White writes:—"Not only had we to make the necessary preparations for observing the Transit of *Venus* at our own stations, but we had also to assist with the requisite observations for finding the positions of the station-

occupied by the different nations in this part of the world. For this purpose the transits of the Moon and culminating stars were observed at every opportunity during the four months commencing with October 1; during the same period also every available occultation of a star by the Moon was observed. Besides this, the stars used by Professor Peters, who had charge of the American party at Queenstown, in New Zealand, in determining the latitude of his position, have been so far as possible observed, also the comparison-stars used by ourselves and by Mr. Tebbutt, of New South Wales, in finding the place of the fine comet of Coggia, which first appeared here in July 1874. Observations were also taken for finding the difference of longitude between our Observatory and Lieut. Harkness's station at Hobart Town."

The usual observations of stars have been made with the Transit-circle, including those for the determination of clock and instrumental errors, close circumpolar stars, low stars for refraction, comparison-stars observed with the Equatoreal, Moon-culminating stars, and those which have been observed by request for some special purpose. The total number of R.A. observations during the year was 2,064, and of P.D. observations 1,150. The principal work done with the great telescope has consisted of drawings of nebulæ and mapping the neighbouring stars. Ten nebulæ delineated by Sir John Herschel have been carefully drawn, and the stars laid down from micrometrical measurements. A drawing of the nebula surrounding *η Argûs*, with the stars accurately inserted, shows no appreciable difference from one made in the preceding year.

Special mention is made in the Report of the new and important instruments which have been added to the establishment. These include the Photo-heliograph used for the Transit of *Venus*, an Equatoreal Refractor of eight inches aperture by Troughton and Simms, a portable Equatoreal of 4½ inches aperture by Cooke, and a double-image Micrometer by Browning. Two barrel Chronographs have also been received, governed by a conical pendulum, mounted according to Huyghen's suggestion, so that the centre of oscillation describes a parabola in moving towards or from the central axis. The advantages of this mechanical contrivance for the registration of transits were fully explained by Mr. Ellery in a paper read by him before the Royal Astronomical Society at the ordinary meeting in December last.

Notes on some Points connected with the Progress of Astronomy during the past Year.

Reduction of the Observations of the Transit of Venus of 1874, *December* 8.

The reduction of the observations made by the British Government Expeditions has been going on for some time at the Royal Observatory, the services of Capt. Tupman, Lieut. Neate, R.N., Mr. Burton, and Mr. Nichol being retained for this purpose. Three computers are also employed.

These reductions may be conveniently stated under the following headings:—

(1) The calculations connected with the determination of the longitudes of Kerguelen Island, Honolulu, and Rodrigues by the lunar observations.

(2) The calculation of all longitudes depending upon the transportation of chronometers, galvanic or other signals.

(3) The determination of the *Greenwich Sidereal Time* of every photograph and phenomenon observed during the Transit.

(4) The determination of the distortion of the images in the photographs.

(5) The measurement of the solar photographs.

(6) The calculation of the *tabular* apparent distances of the centres of the Sun and *Venus* affected by parallax, and of other necessary elements, for the instant of each observation or picture.

In describing the progress which has been made some general remarks may be conveniently introduced.

(1) Altogether there were about 5,000 transits of stars observed for clock and instrumental errors. Nearly the whole of these were reduced as made with the best constants available on the instant, but it was necessary to reduce them all again to insure the utmost possible accuracy in the local time. The re-reduction is complete for the Egyptian stations, and may be said to be about one-half done for the others taken in the mass.

There are in all about 800 observations of the Moon's limb, chiefly in zenith distance, with the corresponding comparisons of clocks, and about 700 observations of stars for latitude. The latter are completely reduced, while with the former everything has been done (refractions computed &c.) to the point where the local time is required. For Rodrigues, however, but little has been done in this respect.

(2) The longitudes of the stations in Egypt (Mokattam, Thebes, and Suez) by galvanic signals direct from Porthcurnow

to Alexandria (the longest line ever telegraphed through), have been elaborately deduced by Mr. Ellis, of the Royal Observatory, and Captain Orde Browne, the latter having re-reduced the whole of the Mokattam transits for the purpose.

The longitudes of the stations at Mauritius and Rodrigues, measured from Suez by Lord Lindsay with 50 chronometers, have been most satisfactorily determined by him. This, of course, formed no part of the Government work, except so far as Lieut. Neate was concerned with it. The transits observed at Rodrigues for clock error &c. in connection with these longitudes have been reduced by Lord Lindsay as well as by Lieut. Neate.

The meridian distance between the Royal Observatory at the Cape and Kerguelen Island was measured by the officers of H.M.S. *Challenger* on her outward voyage; by the United States Expedition in the *Swatara*; and by Lieut. Corbet, R.N., in H.M.S. *Volage*, with twelve chronometers specially picked from the stock at the Royal Observatory. Lieut. Corbet's result agrees to a fraction of a second with the American determination, but differs by some 12ˢ from the *Challenger's*. It is to be remarked that in each case the chronometers were transported but once from the Cape to Kerguelen, never the other way.

About thirty chronometers were employed in twelve journeys made in the Hawaiian Islands for the differences of longitude between the head station at Honolulu and the subsidiary stations at Kailua, in Owhyhee, and Waimea, in Atooi; and twenty chronometers were transported from Honolulu to San Francisco, the rates of which were determined with great care before and after the journey.

The reduction of all this work, as also of similar work for subsidiary stations in Rodrigues and Kerguelen, is very far advanced.

(3) The *Greenwich Sidereal Times* are computed for the Egyptian observations only. The necessary data for Colonel Tennant's photographs having recently been received, these are now in hand.

(4) and (5) The instrument designed by the Astronomer Royal for the measurement of photographs is simple in principle, being intended to measure in one direction only. Two compound microscopes, rigidly connected together, point downwards, one (carrying a fixed wire) on the photograph to be measured, the other (carrying a micrometer wire) on a scale of millimètres etched upon glass. The movement necessary for bisection on the parts of the photograph is made by a screw carrying the whole system, and that on the scale by an ordinary filar micrometer reading directly to the one-five-hundredth of a millimètre. Various devices have been tried, with more or less success, chiefly by introducing engraved diaphragms into the field of view of the microscope, to utilise the photographs with rugged images.

The errors of graduation of the glass scale have been determined, by repeated bisection down to single divisions (millimètres), with great accuracy.

It was, of course, necessary to determine the optical distortion of all the photo-heliographs. For this purpose a very accurately constructed and accurately measured scale of equal parts (lent by Mr. De La Rue) is mounted horizontally over the highest part of the building of the Royal Observatory. Pictures of this scale have been taken at the distance of 400 yards, in such a way as to give the radial distortion in every octant and at intervals of 45″ from the centre of the field. For the determination of the errors of the scale and of the distortion of the five instruments upwards of 6,000 measures had to be made. In addition to the above, some 100 of the solar photographs have already been measured. It is intended to include in the series the photographs taken in Australia by Messrs. Ellery and Russell, and in India by Colonel Tennant.

The greater part of the photographs for distortion have been taken, and all the measurements made by Mr. Charles E. Burton, who will complete the series. It is almost unnecessary to remark that this work could not be in better hands.

(6) For the calculation of the tabular apparent elements required, the Astronomer Royal has prepared several skeleton forms on the normal-centric system, arranged in the following order:—

a. Interpolation of the geocentric R.A., N.P.D., Eq. hor. parallaxes and semidiameters of the Sun and *Venus* for every observation and picture.

[To facilitate this, these quantities have been interpolated *and printed* for every ten seconds of Greenwich sidereal time, from the first external contact most accelerated, to the last external contact most retarded. Copies are distributed by the Astronomer Royal to every computer, English and foreign, on application to him.]

b. Calculation of the parallaxes in R.A. and N.P.D.

c. Computation of tabular local distances between the centres of the Sun and *Venus*, and of factors of corrections to time, R.A., N.P.D., and parallax.

For the Egyptian observations the local tabular quantities have been computed. Colonel Tennant's are in hand.

The above will give the great mass of information necessary to form the final equations given in the Astronomer Royal's paper in the *Monthly Notices*, Vol. xxxv., p. 287.

This work finished *and printed*, it will be a matter for consideration whether this country should continue the calculations necessary to deduce a value of the solar parallax from the British observations only, or wait until the results of all nations can be brought together and the whole subject treated in the desirable manner indicated in the concluding paragraph of the Astronomer Royal's paper alluded to above.

The following is a list of more or less successful stations whence the Transit of *Venus* was observed, from information

hitherto received at the Royal Observatory, or through *Silliman's Journal*, *Comptes Rendus*, and other publications:—

I signifies ingress; E, egress. A number following these letters indicates the number of observers when known. P, ordinary photographs; J, Janssen photographs. M, micrometric measures; Hel., heliometer measures, followed by their numbers when known. For American and British stations the numbers refer to *measurable* photographs.

Australia:		
Adelaide	British	E. 2. M. 60.
Melbourne	„	I. 3. E. 3. P. 200. M. 44.
Sydney	„	I. 2. E. 2. P. 180. J. 560.
Windsor	„	I. 1. E. 1.
Burmah:		
Bamo	?	I. 1. E. 1.
Beyrout	?	E. (?).
Cape of Good Hope	British	E. P. 14.
Ceylon:		
Colombo	„	I. 1. E. 1.
Egypt:		
Cairo	„	E. 3. M.
Gondokoro	„	E. 1.
Suez	„	E. 1. M.
Thebes	Russian	E. P.
Thebes	German	E. P. Hel.
Thebes	British	E. 1. P. 35. J. 120. M.
India:		
Bushire	„	I. E.
Calcutta	„	I. E.
Kurrachee	„	No information.
Maddapore	Italian	I. E.
Roorkee	British	I. 2. E. 2. P. 100. J. 420. M.
Islands:		
Auckland	German	E. P. Hel.
Bourbon	Dutch	E. P. (a few).
Chatham	American	P. 8.
Hawaiian (2)	British	I. 5. P. 60. M. 120.
Kerguelen	„	I. 1. E. 3. P. 13.
Kerguelen	German	I. E. P. (?).
Kerguelen	American	P. 26.
Mauritius	German	P. Hel.

Islands—*cont.*		
Mauritius	Lord Lindsay's	E. 3. P. 100. Hel.
Mauritius	British	I. 1. E. 1.
New Caledonia	French	I. P. 100.
Rodrigues	British	I. 3. E. 3. P. 58. J. 405. M. 10.
St. Paul	French	I. E. P. 500.
Japan:		
Kobe or Hiogo	„	I. E. P.
Nagasaki	American	I. E. P. 60.
Nagasaki	French	I. E. P. J. M.
Yokohama	Russian	I. E. P. (?).
Yokohama	Mexican	I. 2. E. 2. P. 100. (?).
New Zealand:		
Bluff Harbour	German	I. P.
Christchurch	British	P. 9. M.
Queenstown	American	I. P. 59.
Persia:		
Ispahan	German	P. 19.
Teheran	Russian	I. E. P.
Russia and China:		
Habarowka:	„	I.
Jalta	„	E.
Kiachta	„	I. E. P. 8.
Nertschinsk	„	I. E. Hel.
Orianda	„	E.
Port Possuet	„	I. E. P. 38.
Pekin	American	I. E. P. 90.
Pekin	French	I. E. P. 60.
Tschifù or Cheefoo	German	I. E. P. Hel.
Tschita	Russian	I. E. Hel.
Wladiwostok	„	E. M.
Wladiwostok	American	I. E. P. 13.
Tasmania:		
Campbell Town	„	E. P. 55.
Hobart Town	„	P. 39.

The Total Eclipse of the Sun of 1875, *April* 6.

The observations of this eclipse were unfortunately not very successful, principally on account of unfavourable weather. Extensive preparations were made, and a code of instructions

drawn up under the supervision of a Committee of the Royal Society, but although the arrangements were necessarily hurried at the last moment, owing to the limited time available before the departure of the observers from England, it was fully anticipated, had the sky been clear during totality, that some important photographic results would have been secured. The eclipse was an important one, and the duration of the total phase was considerable in the Nicobar Islands, at Mergui on the Tenasserim coast, and in Siam, districts easily accessible from India, and from England by the Peninsular and Oriental line of steamers. On the application of the Royal Society Committee, Government most handsomely granted the sum of £1,000 in aid of the expedition, as well as giving encouragement and assistance in other ways. It was originally intended to make Mergui one of the observing stations; but the meteorological conditions of the Tenasserim coast in April were considered too doubtful, while at Camorta, one of the Nicobar Islands, the weather at this time of the year was represented as being peculiarly favourable. It was, therefore, finally decided to have two observing stations; one at Camorta, and the second as near as possible on the central line of shadow at some convenient spot near Bangkok, Siam. At Camorta, Captain Waterhouse, Professor Pedler, and Signor Tacchini, on the part of the Indian Government; and Dr. Vogel, Mr. Mendola, and Mr. Reynolds, on the part of the Eclipse Committee, with several assistants, were the observers. Captain Waterhouse and Mr. Reynolds had each some previous experience in the practical manipulation of eclipse photography, the former having ably assisted Colonel Tennant at Dodabetta, in 1871; while the latter was photographic assistant to Mr. De La Rue in Spain, in 1860. The station in Siam was at Bangtelue, near Chulai Point, some forty miles from the mouth of the Bangkok river, along the west coast of the gulf, and it was occupied by Dr. Schuster, as chief, assisted by Mr. Lott, Mr. Beazley, some officers of H.M.S. *Lapwing*, and by Captain Loftus and other European residents in Siam. M. Janssen, although not officially attached to the English party, also chose this station for his observations, his instrument having been fixed about fifty yards from the others.

As the sky was not altogether clear at either station, especially at Camorta, which prevented the spectrum of the chromosphere being recorded on the photographic plates, it is scarcely necessary to give even an outline of the plan of observation proposed by the Eclipse Committee. It is sufficient to remark that the observations were not intended to embrace eye-estimations of the forms and positions of the solar prominences and corona, as in all former eclipses of the Sun; but an attempt was to be made during totality to register photographically the spectra given by the different layers of the chromosphere and coronal atmosphere, by the aid of spectroscopes and prismatic cameras used in conjunction with telescopes. At Camorta the sky

was completely overcast at the critical moment; but in Siam the weather was more favourable, but with a hazy sky, allowing, however, the principal phenomena of the eclipse to be seen. At this station several ordinary photographs of the corona were secured, but those taken with the spectroscopic camera show no result of importance on the plates. An eye-sketch of the corona was also made by Lieutenant the Hon. H. M. Shore. Mr. Lott, one of the observers, in giving a brief account of the proceedings at Bangtelue, remarks (*Nature*, vol. 12, p. 172):—"There were two sets of instruments employed as telespectroscopes, one working in the large Observatory, the other in the siderostat Observatory, where we had the large new siderostat working with Mr. Lockyer's 9¼-in. reflecting telescope and a spectroscopic camera. The first two instruments were in splendid order, working together beautifully; but the spectroscopic camera, not having been tested previously, could not be brought to give anything like a well-focussed photograph prior to the eclipse. The image of the corona, which appeared very distinct and bright on the slit-plate, although exposed during the whole of the totality, gave no visible results on the photographic plate; even the Sun itself, exposed for two seconds for the purpose of obtaining an index, gave likewise no result." These negative observations are not, however, without their value, as some useful lessons can probably be gathered from them which may be turned into practical account in future observations of a similar kind. Dr. Hooker, in his address delivered at the anniversary meeting of the Royal Society, thus briefly alludes to the results of the observations of the Siam party:—"The most important results obtained are (1) a series of photographs of the corona, taken with a prism of small angle in front of the object-glass, which show several rings and part of the form of the outer corona; and (2) a series of views of the corona, chiefly taken at different times of exposure. The discussion of the observations has not yet been taken in hand; but it is not too early to state that several results of great interest and value have been secured."

The following extracts from Captain Waterhouse's Report to the Secretary to the Government of India are interesting, notwithstanding the total failure of success of the proposed operations. Captain Waterhouse states that: "There had been a little rain in the night, but the morning was fine; there were light clouds about the horizon, but above, the sky was nearly clear, and it continued fine till the time of first contact, which was observed by Signor Tacchini and Mr. Loder at $11^h\ 58^m\ 41^s.4$, as described in Signor Tacchini's memorandum. Shortly after this, light haze and clouds began to gather, and the rare phenomenon of a solar halo was seen. Though the aspect of the sky began to look unpromising, our preparations were not allowed to relax in the least, and a full rehearsal was gone through by Mr. Pedler and myself, and repeated two or three times. During these rehearsals

the zenith was quite clear, but ominous masses of clouds gathered up on both sides of the eclipsed sun, gradually closing it in, and heavy rain was seen in the direction of the N.W.

"After the rehearsals lamps were lighted and the final preparations made. About 1 o'clock, when the signal was given for preparing the photographic plates, the sky had clouded over almost entirely, and all hope of obtaining good results had been given up. I was only just able to adjust the focus of my instrument and start the clock, when thick clouds closed up completely over the Sun and hid it entirely from view. I noticed, too, that the wind, which had been blowing from the south-east, changed and blew from the north-west.

"Signor Tacchini had calculated the time of commencement of totality at $1^h\ 22^m\ 14^s{\cdot}7$, local mean time of Camorta, and it was arranged that at the moment the totality commenced he should give the word to a sepoy to fire a gun. The plates were ready by about 15 minutes to 1, and we all took our places in readiness for Signor Tacchini's signal, the time-keeper warning us at every minute. Shortly before the estimated time of totality I gave the signal "count 0" to Mr. Cox, and as I could see from the light that totality had not commenced, he continued to count 0 till I gave the word "count" at the moment when it became quite dark, and then at once commenced counting seconds from one onwards. I told Private Fox to uncover the lens, and kept it uncovered in case of a break in the clouds permitting a glimpse of the corona, and I remained watching the sky, vainly hoping to see a rent in the dark veil which hid from us the bright and glorious sight we had come so far and laboured so earnestly to record; but during the whole totality the sky remained completely overcast, and not a glimpse of the corona could be seen. It was not quite dark, and, so far as I can recollect, not so dark as at Dodabetta, but like a dark twilight on a stormy evening. The sky and surrounding objects were tinged with a dark purple-grey tone, but around the horizon to the west the sky was of a light golden orange, making a picturesque contrast with the dark lurid masses of clouds.

"At the Browning reflector and Janssen apparatus Messrs. Pedler and Mackay were well prepared, and Professor Pedler states that at the moment when totality seemed to commence, as shown by the sudden darkening of the sky, one of the photographic plates was exposed in the camera attached to the Browning reflector and allowed to remain so until about five seconds before the calculated end of totality, when it was shut off. On being subsequently developed, no trace of any image or spectrum could be obtained. There was, however, sufficient diffused light in the sky to give a visible spectrum in a small Herschel-Browning direct-vision spectroscope, with which he examined the faint light which was given out by the clouds, and also by one or two bright spots of land about a mile off, where the coronal light appeared to reach, but in each case could only detect a faint solar

spectrum in which three or four of the principal Fraunhofer lines were visible."

The clouds gradually dispersed after the totality, enabling Signor Tacchini to make a few spectroscopic observations of the cusps about 20 minutes before the end of the eclipse, which was recorded by several observers at $2^h\ 48^m\ 17^s$ local Camorta time, the sky being nearly clear. Although the phase of the eclipse was so small when Signor Tacchini examined the cusps, he was able, by narrowing the slit, to see the reversed lines of Magnesium, 1474 K, and the four ordinary lines between *b* and F. He remarks that these lines are the same as those seen at Palermo almost every day, and that, being visible so near the end of the eclipse, they gave a good indication of what might have been seen in the cusps near the time of totality had the sky been perfectly clear.

At Mergui, on the Tenasserim coast, where it was at first decided to have a station, but which was abandoned on account of the greater probability of bad weather on that coast than at Camorta, the sky was absolutely cloudless and free from haze during the totality.

Solar Physics.

The Italian Spectroscopic Society has continued its labours during the past year, and the solar prominences have been regularly delineated by Padre Secchi and Professor Tacchini, the latter of whom has also devoted special attention to the observation of the bright lines, *b* (Magnesium) and 1474 K. From a long series of observations he finds that both lines are seen at the base of prominences, and sometimes all round the Sun's limb, and that their brightness increases with that of the chromosphere, 1474 being usually the brighter, and frequently seen when *b* is absent. It appears also that there are special regions of magnesium corresponding with those of the faculæ, and that magnesium is chiefly found in the northern hemisphere.

Padre Secchi has given, both in the *Memorie degli Spettrosc. Italiani* and in the *Comptes Rendus*, the results of his observations of Sun-spots and prominences during 55 rotations, from 1871, April, to 1875, June, a period of decrease of solar activity. His conclusions are: 1. That the daily number of prominences has decreased (from 15 to 4) with the decrease in the spots, and that the great eruptions of metallic vapours have altogether ceased. 2. That the distribution of the prominences has changed greatly in the four years, the two maxima which formerly existed at the north and south poles having now disappeared, leaving only the two about latitude 20° north and south, which have been persistent throughout. 3. That prominences of great height or breadth are now rare, though the mean height has not much

diminished. 4. That the wreaths of faculæ formerly found near the poles have disappeared, together with the prominences, implying a connection with these rather than with the spots.

Mr. Langley has entered on the question of the structure of the Sun in a paper in the *American Journal of Science*, accompanied by a beautiful drawing of a typical Sun-spot which he examined very minutely in December 1873. In this spot he found that the filaments both of the penumbra and umbra were disposed in spiral curves, and that they showed a tendency to grow brighter at the tips, so that it was difficult to resist the impression that they curled upwards, lifting their points above an absorbing medium. The umbra proved, when all extraneous light was excluded, to be not only far from black, but insupportably bright to the naked eye, and the filaments were well seen in this part of the spot. Though Mr. Langley considers the filaments or plumes as distinct entities, he is not prepared to regard them as "photospheric crystals," their size being so enormous (10,000 miles long by 5,000 broad); and he prefers to class them with the filaments or jets of hydrogen in the chromosphere, and with certain forms of cirrus in our own atmosphere. As the result of his examination of this and other spots, Mr. Langley concludes that if a liquid or viscous solar shell exist, it must be at a considerable depth below the photosphere; that the hypothesis which regards the umbra as a sort of stagnant pool of cool vapours, depressing by their weight the general surface, can hardly be reconciled with the existence of a bright sharp inner edge to the penumbra and with the structure in the umbra; and that, finally, a cyclonic or vortical action appears to be the chief agent in the formation of such a spot. P. Secchi has pointed out in reply to this (*Mem. degli Spettr. Ital.*) that there are three periods in the existence of a Sun-spot: 1. the formation; 2. the stationary period; and 3. the disappearance; and that it is only in the latter two that a stagnant cloud of cool vapours is formed. The formation of a spot he holds to be due to eruptions of metallic vapours from within the Sun, and it is to this period only that he thinks Mr. Langley's observations apply. The difference between his views and those of M. Faye would thus be that he attributes the upward motion to an eruption of vapours during the formation of a spot, whilst M. Faye ascribes it to the action of a cyclone; which Secchi disputes on the ground that there is no continuous rotation to be seen in a spot.

Mr. Langley has also given (*Comptes Rendus*) the results of his investigation of the relative temperatures of different parts of the Sun's surface, in the course of which he has verified the discovery made by Prof. Henry in 1845, that the umbra of a spot radiates less heat than the surrounding chromosphere, and has also tested Secchi's statements that the heat from the Sun's limbs is only half of that from the middle of the disk, and that the equatoreal regions are hotter than the polar. Mr.

Langley used a refracting telescope of thirteen inches aperture, and enlarged the focal image of the Sun to a circle two feet in diameter. A thermopile composed of sixteen pairs of very small elements, and connected with a Thomson mirror-galvanometer, was placed in different parts of the enlarged image, the thermopile being inclosed in a double cylinder containing water at a constant temperature. With this arrangement Mr. Langley found that the umbra of a spot was much cooler than the *neighbouring* photosphere, but that it actually radiated more heat than the bright surface close to the limb, and that, therefore, the absorption of light in the case of a spot was not accompanied by a corresponding absorption of all the heat-rays. Taking Sir W. Herschel's estimate of the brightness of the umbra as $\frac{7}{1000}$ of that of the photosphere, Mr. Langley infers that the proportion of the solar heat radiated by a spot is fifty times as great as that of the light; and a similar disproportion, though not to so marked an extent, exists for the photosphere near the limb. From a comparison of the heat received from the equatoreal and polar regions (at equal distances from the middle of the disk), Mr. Langley concludes that there is no such difference now as Secchi found in 1852.

M. Faye remarks on this, that if the equatoreal regions be no hotter than the polar, all analogies founded on terrestrial phenomena such as trade winds must be false, and that the currents in the Sun must be parallel to the equator, which would tend to support his theory of the formation of Sun-spots.

Mr. Langley has more recently (*American Journal of Science*) turned his attention to the question of the amount of absorption of the luminous rays by the solar atmosphere, a point on which most diverse conclusions have been arrived at by different observers, Arago finding the diminution of light at the Sun's edge to be only 2·4 per cent., whilst Liais gives 10 per cent., and Secchi no less than 78 per cent. To eliminate the sources of error to which these determinations appear to be subject, Mr. Langley has arranged an apparatus to which either Bunsen's or Rumford's photometer may be applied, the principle being that a large image of the Sun is formed on a screen by an amplifying lens applied to the equatoreal, and that the cones of rays from the two parts of the solar disk to be compared are, after passing through two equal small holes in the screen, reflected by right-angled prisms towards each other (in a direction parallel to the screen), being thus under precisely the same circumstances as the rays from two lights to be compared in the ordinary use of these photometers. A Bunsen's disk (a small sheet of paper, in the centre of which is a spot of oil) slides on the common axis of the two cones of rays, the relative brightness of the two parts of the Sun's image being measured by their relative distances from the disk when the spot of oil becomes indistinguishable through the equality of the illumination on the two sides. Mr. Langley has also used Rumford's photometer in a somewhat similar way,

and finds that there is a difference of hue as well as of tint, the two shadows cast by a rod on a screen parallel to it, and illuminated respectively by the edge and centre of the Sun's disk, being chocolate red and bluish (London smoke), from which it may be inferred that, if the solar atmosphere were removed, the Sun's light would become more blue. From his various observations, Mr. Langley concludes that about half of the Sun's light is absorbed by its atmosphere; and, assuming as a probable hypothesis that four-fifths of the 500° Fahr. which is the mean absolute temperature of our globe is derived from the Sun, he infers that an increase of 25 per cent. in the absorption of its atmosphere would lower the surface temperature of the Earth by 100° Fahr. Even if we suppose the temperature of space to be no lower than what has been actually observed in Arctic regions, such an increase of the absorption would bring the Earth back to the temperature of the glacial epochs. Mr. Langley thinks, therefore, that a change in the solar atmosphere since 1852, such as Secchi assumes, would have altered the mean temperature of our globe to a sensible amount, and therefore concludes that no evidence of real change has yet been established.

By applying similar photometric methods to the umbræ of spots, Mr. Langley finds that the average nucleus is at least five thousand times as bright as the Moon.

Prof. Mayer has invented a method for registering isothermals of the Sun's disk, depending on the fact that Meusel's double iodide of copper and mercury blackens at a temperature of 70° C. The blackened surface of a sheet of thin paper coated with the iodide on the back is exposed to the image of the Sun formed in a telescope, and the different isothermals obtained by using different areas of object-glass. Prof. Mayer's conclusions are: (1) that there exists on the solar image an area of sensibly uniform temperature and of maximum intensity; (2) this area of maximum temperature is of variable size; (3) this area of maximum temperature has a motion on the solar image; (4) the area of maximum temperature is surrounded by well-defined isothermals, marking successive gradations of temperature; (5) the general motions of translation and of rotation of these isothermals appear to follow the motions of the area of maximum temperature which they inclose, but both central area and isothermals have independent motions of their own.

The Minor Planets.

Great additions have been made to the known members of this remarkable group of minute planetary objects, which at the present time number 159. Seventeen have been added to the list since the last anniversary, while in the month of November alone six were discovered in Europe, four at Pola, by M. Palisa,

and two at the Paris Observatory, by MM. Paul and Prosper Henry. The following table contains the dates and places of discovery, the names of the discoverers, the magnitude of each planet when first detected, the mean distance from the Sun, and the sidereal period :—

No. of Planet.	Name.	Date of Discovery, 1875.	Place of Discovery.	Discoverer.	Mean Distance.	Sidereal Period.	Mag. when discovered.
143	Adria	Feb. 23	Pola	Palisa	2·75	1668	12
144	Vibilia	June 3	Clinton, U.S.	C. H. F. Peters			11
145	Adeona	„ 3	„	„	2·69	1615	12
146	Lucina	„ 8	Marseilles	Borrally	2·71	1627	12
147	Protogeneia	July 11	Vienna	Schulhof	3·13	2018	12
148		Aug. 7	Paris	Prosper Henry	2·77	1683	12
149		Sept. 21	Toulouse	Perrotin			13
150		Oct. 18	Ann Arbor, U.S.	Watson	2·98	1880	10-11
151	Abundantia	Nov. 1	Pola	Palisa	2·58	1517	12
152	Atala	„ 2	Paris	Paul Henry	3·13	2025	12
153	Hilda	„ 2	Pola	Palisa	3·95	2868	12-1
154		„ 4	Paris	Prosper Henry	3·22	2111	12
155		„ 8	Pola	Palisa			12
156	Xantippe	„ 22	Pola	Palisa	3·04	1934	12
157	Dejanira	Dec. 1	Marseilles	Borrelly	2·59	1519	13
		1876.					
158	Coronis	Jan. 4	Berlin	Knorre	2·99	1889	12
159	Æmilia	„ 26	Paris	Paul Henry			12-13

From elements calculated by Herr Kühnert of Vienna, the period of revolution of (153) *Hilda* is found to be about eight years, and therefore longer than that of any other minor planet, the mean distance being 3·95. Elements have likewise been calculated by Dr. A. Schmidt, who also makes the mean distance 3·95. The four outermost of the minor planets previously discovered are *Cybèle*, *Hermione*, *Sylvia*, and *Camilla*, with mean distances respectively of 3·43, 3·46, 3·49, and 3·56. That of *Camilla* is, however, doubtful, as it is determined from uncertain elements. The sidereal period of *Hilda* is 2,868 days, while that of *Flora*, the nearest minor planet to the Sun, is 1,193 days.

Planets (141) and (142), unnamed at the date of the last Report, are now known as *Lumen* and *Polana*.

The amount of calculation which falls upon those who have undertaken to provide annual ephemerides of the minor planets has now become so onerous that it is feared that it will be found impossible to keep a proportional pace with such numerous discoveries as are now made yearly, and that many of the more

recently discovered planets may be ultimately lost (as a few already appear to be) for want of sufficient observations for the determination of correct elements of their orbits. Some very important remarks on this subject which appeared in *Nature* (November 18, 1875), evidently written by one eminently qualified to give an authoritative opinion, may very appropriately be reprinted here.

"The rapid increase in the number of small planets must soon occasion serious difficulty, not only in predicting their positions with sufficient approximation to allow of their being recognised without considerable expenditure of time and trouble, but likewise in securing observations, especially on the meridian, according to the system pursued for some years past at Greenwich and Paris, by agreement between the Astronomer Royal and M. Le Verrier.

"As regards the preparation of ephemerides, it is well known that the conductor of the *Berliner Astronomisches Jahrbuch*, Professor Tietjen, makes it a speciality of his work, with the aid of a numerous body of astronomers in various parts of Europe and in the United States, and hitherto he has succeeded in providing observers with an ephemeris of nearly every small planet detected to within a short time of publication. Thus, in the *Jahrbuch* for 1877, we find approximate places for 1875 of 134 out of 138 planets—materials for calculation not being available in four cases—and accurate opposition-ephemerides are given where the elements have been perturbed to the year, and for those planets for which tables have been prepared. The initiated in these matters will be aware that a work of this extent involves a vast amount of labour, which will be greatly increased with the present rate of discoveries of new members of the group of small planets.

"In some few instances the perturbations have been determined with every possible precision, with a particular object in view, as in the case of *Themis*, the motion of which was rigorously investigated by Dr. Krüger, for a determination of the mass of *Jupiter;* and for those planets whose perturbations have been thrown into the form of tables, it was also necessary to settle the elements with great accuracy, though the results have not been in every case so satisfactory as might have been expected. We have now Tables of *Amphitrite*, by Becker; of *Iris*, *Flora*, and *Victoria*, by Brünnow; *Egeria*, by Hansen; *Metis*, *Lutetia*, and *Pomona*, by Lesser; and of *Parthenope*, *Eunomia*, *Melpomene*, and *Harmonia*, by Schubert. Even with approximate places of these bodies, so long as they are situated within about 3° from the ecliptic, the charts of small stars now in the hands of astronomers allow of their being identified without much difficulty with the equatoreal; and the errors of the predicted places being determined by this instrument, their meridional observation is greatly facilitated. Still, rough ephemerides must be prepared, and a considerable amount of time will be involved in ascertain-

ing their errors; and, as observations made with this purpose in view may be so conducted as to give positions pretty nearly as reliable as those generally resulting from meridional observations, we shall not be surprised to learn that the latter are soon relinquished, except, perhaps, for the older minor planets, and for such as attain the brightness of stars of the eighth or ninth magnitude, and are accurately predicted. The subdivision of labour, as regards observations, does not appear to have so far worked very efficiently, though proposed many years since. Another effort, however, may be necessary in this direction, and it may at least be expected that those who by their discoveries are so rapidly increasing the list of planets, will keep them in view for a sufficient length of time to allow of their elements being well determined."

Encke's Comet.

In the last Annual Report the Council recorded the discovery of six new Comets, and the re-detection of the two periodical Comets of Encke and Winnecke, which had taken place during the preceding twelve months. In striking contrast to this, as well as to the unusually large number of planetary discoveries, no fresh discovery in the cometary system has been announced during the past year. A few remarks may, however, be made on the observations obtained of Encke's Comet during its recent approach to perihelion, whose detection at that appearance was reported last February.

It subsequently appeared that this Comet was first seen by Professor Holden, with the 26-inch equatoreal of the Washington Observatory, on the evening of January 26, 1875. Even with that object-glass, however, it was extremely faint, and only just observable. On the following evening it was independently detected by M. Stéphan, at the Observatory at Marseilles. Both on that occasion, and some nights afterwards, he found the observations extremely difficult, the comet having the appearance of a small milky spot, with its boundary quite undefined, and without any point of condensation. On February 28 it was observed by M. Struve with the great refractor at Pulkowa; after which a series was obtained by Herr C. F. W. Peters at Kiel, and a longer one by Professor Bredichin at Moscow—the last observation of the latter series being made on the evening of April 10, only three days before the comet was in perihelion, so that its increased northern declination alone made observation possible. Early on the morning of May 8 it was detected in the southern hemisphere by Mr. Tebbutt, of Windsor, New South Wales, who stated that the comet was "so excessively faint that the positions obtained were necessarily rough."

Dr. Von Asten, to whom is due the ephemeris by which these

observations were obtained, and who, in fact, has had the comet under his care for some years past, has written some remarks concerning it, which are interesting as bearing upon the undecided question of the so-called "resisting medium" in space. That an acceleration in the period of the comet has taken place does not now admit of doubt, but there are some remarkable facts in connection with it which still await their final solution. This acceleration did not take place at or near the perihelion passage of 1868; and Von Asten finds that the observations in 1865 and 1871 are perfectly consistent with the supposition that the comet moved between these times, according to the ordinary law of gravitation, without any effect traceable to a resisting medium, or any other extraneous cause of disturbance other than the planetary perturbations. And although he does not claim infallibility for his calculations, and wishes as much as anyone (he remarks) that they should be independently checked, the great care he has taken and the examination he has made leave a strong impression upon his mind that they are correct, and that all the perturbations have been accurately applied. A consideration of the whole matter, and of Encke's earlier calculations, as well as his own recent labours, has convinced him that the elements of the comet suffer changes in the immediate neighbourhood of the perihelion, which cannot be explained by the theory of a resisting medium, and rather carry him back to Bessel's opinion, that the extraordinary disturbance to which that body is subject is closely connected with the out-streaming phenomena. The subject, of course, is one which invites and will receive further investigation. The result of the observations made at the last appearance (which was a most unfavourable one for good observation) seems to be that an acceleration of the usual character showed itself, but of only about two-thirds of the ordinary amount, thus confirming the idea of its being connected with changes in the interior constitution of the comet.

Attention may also be directed to some spectroscopic observations of Encke's Comet, made at the end of March, by M. Von Konkoly, of the O-Gyalla Observatory, who first saw it on the 22nd of that month. The observations were made before the evening twilight had quite disappeared, and on applying the spectroscope Von Konkoly was surprised at the brightness of the spectrum, considerably exceeding that of Coggia's Comet on June 3, 1874. There were three bright bands, the centre one the brightest, all diffused at the edges. He could see no trace of a continuous spectrum. The comet had a nucleus, very excentrically situated with respect to the Sun, and about equal to a star of the twelfth magnitude. Under high powers it had a granulated appearance. On March 26 a tail was noticed on the opposite side to the position of the Sun, which was equal in length to the diameter of the comet.

D'Arrest's Periodical Comet.

An elaborate discussion of the orbit of D'Arrest's periodical Comet has been made by M. Leveau, of the Paris Observatory, who, availing himself of the previous investigation of M. Villarceau, had already calculated new elements for the epoch 1869, October 13·0, taking into account not only the perturbations produced by *Mars*, *Jupiter*, and *Saturn*, but also by *Venus* and the *Earth*, near the time of perihelion passage. He was thus able to calculate an ephemeris, by the aid of which the comet was detected at the end of August 1870.

In the present investigation, M. Leveau has formed four groups of the observations made during this apparition, and by a comparison with his ephemeris he has deduced four normal positions, which, added to those formed by M. Villarceau for 1851 and 1857, gave the means for the correction of the elements which he intended to adopt as the basis of his work. For the corresponding epochs to these normal positions, M. Leveau has calculated equations of condition which have furnished a series of equations, the solution of which has convinced both M. Villarceau and himself, that for this comet, one of the most interesting of those whose periodicity has been proved, the question could not be solved in the usual manner. Why this is the case M. Leveau gives the following explanation:—"In 1861 the comet approached very near to *Jupiter* (0·36 of the mean distance of the Earth from the Sun), and the influence of this large planet has been so considerable, that the variations of the perturbations produced by it were sensibly of the same order as the variations of the elements of the comet, so that, to obtain the corrections to the elements, the equations of condition, calculated according to the usual astronomical methods, are not sufficient for the purpose. M. Villarceau and I have, therefore, considered that the difficulty which has presented itself could only be surmounted by the employment of the method of assumed positions.

"Consequently I have been obliged, for the determinations of the equations of condition of 1870, to calculate the perturbations, about the epoch of the nearest approach to *Jupiter*, with six series of elements differing slightly from the original elements, and to deduce, from the variations produced by each of these hypotheses in R.A. and Declination of the normal positions of 1870, the coefficients of the equations of condition for the corresponding epochs. Combined with the equations of 1851 and 1857, these equations have formed a series of twenty-five equations; and solved by the method of Cauchy, they have furnished me the corrections to apply to the elements of 1851, so that the whole of the observations from 1851 to 1870 may be represented." The resulting osculating elements, from the combined researches of M. Villarceau and M. Leveau, are as follows;—

Epoch: 1869, July 8·72075, Mean Time Berlin.

ϵ	=	322	54	23·14
ϖ	=	322	54	17·82
θ	=	148	23	18·10
ϕ	=	13	55	11·85
η	=	41	14	42·57
n	=	555″·23987		

Mean Equinox and Ecliptic, 1850·0.

Treating the elements for 1869 in a similar manner to those for 1851, the following osculating elements have been obtained:—

Epoch: 1869, October 13·0, Mean Time Berlin.

ϵ	=	266	57	5·92
ϖ	=	318	41	3·56
θ	=	146	25	35·64
ϕ	=	15	39	25·96
η	=	39	25	16·35
n	=	540″·28076		

Mean Equinox and Ecliptic, 1870·0.

The comparison of the observations from 1851 to 1870 with places calculated from these elements give residuals which do not appear to be very considerable, when the extreme difficulty of observing so faint an object, and the magnitude of the perturbations affecting the comet between 1851 and 1870, are taken into consideration. The effect of these perturbations has been to alter the Right Ascension and the Declination on September 24, 1870, by the following quantities: δ R.A. $-14^\circ\ 35'\ 14''$ and δ Decl. $+\ 7^\circ\ 37'\ 13''$.

Munich Catalogues of Telescopic Stars.

Further progress has been made in the publication of Dr. Lamont's valuable zone-catalogues of small stars since the notice in the Annual Report for February 1873 was written. The thirteenth supplemental volume to the *Annalen der Munchener Sternwarte* contains additional catalogues of the observed R.A. and Declination of telescopic stars included in zones extending from 27° north declination and 33° south declination. The numbers of the stars observed in the different zones are—

1818	contained between	$+15^\circ$	to $+21^\circ$ Declination.
630	„	„	$+21$ „ $+27$
1621	„	„	-15 „ -21
904	„	„	-21 „ -27
591	„	„	-27 „ -33

In addition to these new zones, the volume also contains two supplements to the former catalogues, consisting of places of 3,466 stars situated between 15° north declination and 15° south declination. These supplements contain, respectively, 918 and 2,548 stars. As in the preceding catalogues, the magnitudes are mostly from the eighth to the tenth; and reliable places of stars of this class are often found most valuable for comparison with faint objects, whether they be minor planets, comets, or nebulæ. The comparison of the catalogue-places with those determined from the observations of Lalande, Bessel, Rümker, and Schjellerup is continued for each corresponding star. In most instances the average differences between the resulting right ascensions and declinations in Lamont's Catalogues, and of those with which they are compared, are of small amount; but in some cases they are considerable, far greater than could be referred to ordinary errors of observation, but perhaps not more than might be expected to be found from the discussion of the observations of so many thousands of minute stars.

Moscow Observations.

Last year the publication of the first volume of Observations made at the Observatory of Moscow was reported, and the Council expressed much pleasure in noticing the appearance of this contribution to astronomy emanating from a new observatory. They are glad, therefore, to notice the publication of the first and second parts of Volume II., which contain a series of papers on miscellaneous observations made principally in 1874 and 1875. The subjects included in the first part are, Observations and Drawings of *Jupiter*; Astronomical and Physical Observations of Comet III, 1874 (Coggia); Micrometrical Measures of *Juno* in Declination; Spectroscopic Observations of the Sun; the August Meteors, 1874; Examination of the Errors of the Meridian Circle; and an Auxiliary Table for the Calculation of Refraction. The second part contains a continuation of the Physical Observations of the Sun and *Jupiter*, made in 1875; a series of Observations of Encke's Comet, made between February 25 and April 10, 1875, and other miscellaneous papers.

Several of these papers are illustrated with plates of drawings or photographs, especially those on the Spectroscopic Observations of the Sun, to which are attached plates representing the form and magnitude of the Solar prominences between May 8 and October 13, 1874, and between April 25 and August 29, 1875. Drawings of the head of Coggia's Comet, and seventeen pictures of *Jupiter*, drawn at intervals between March 13 and May 18, 1874, and nineteen between April 23 and May 24, 1875, are worthy of examination.

The publication of the zone-observations of stars of the

seventh and eighth magnitudes, alluded to last year, as well as other observations accumulated since 1861, will be continued as soon as the reductions are completed. Dr. Bredichin has, however, acted wisely in issuing his recent observations without waiting for these star reductions, as their value is much increased by a speedy publication, thus giving an opportunity for their early comparison with corresponding drawings and observations made at other observatories.

The Pleiades Group.

M. Wolf, of the Paris Observatory, has made a series of measurements of this interesting group of stars, including all visible through an object-glass of 0·31 millimètre aperture. The exact positions of the 53 stars observed by Bessel, referred to *η Tauri* by differences of right ascension and polar distance, are given in a table containing the measurements of M. Wolf, compared with those of Bessel reduced to 1874, January 1. The relative magnitudes of these 53 principal stars have been determined with very great care, in order to detect any possible variation, of brightness since Bessel's observations. M. Wolf has been able to detect no less than 499 stars around *η Tauri*, contained within a rectangle of 135 minutes of arc in length and 90 minutes' breadth. These vary from the third to the fourteenth magnitude. The observed magnitudes have been compared with those in the Catalogues of Jeaurat, Lalande, Piazzi, Bessel, and Argelander; from which M. Wolf concludes that among the eight principal stars of the group, *Merope* and *Atlas* are decidedly variable, and *Maia* appears also to have increased in magnitude since the observations of Piazzi and Bessel. The five others show no evidence of variability, but some of the smaller stars have certainly changed their relative brightness since the former observations.

The most remarkable object of the group is the nebula around *Merope*. Discovered by M. Tempel in 1859, it has also been seen by Professors D'Arrest and Schmidt, who were of opinion that the nebulosity must be variable. On 1874, March 7, it consisted of two portions, one of which was nearly concentric with *Merope*, but extending slightly towards the east; the other, more luminous, was about seven seconds of arc from the star, on the same parallel, the diameter being about one second. From the month of November, 1874, to the end of February, 1875, the nebula was invisible, although it was looked for on many occasions when the sky was very favourable for the purpose. M. Wolf, therefore, considers that this nebula is certainly variable, with a moderately short period.

He concludes, from a comparison of the differences between his and Bessel's measurements of the 53 principal stars that the

Pleiades form a group whose members are physically connected one with the other; and, moreover, there appears to exist in the group a relative displacement of the stars, which carries the greater number of them in a contrary direction to the diurnal motion, slightly diminishing their polar distance. M. Wolf hopes that his two years' observations may serve as a certain basis, at a future period, for the determination of the proper motion of the separate components forming the *Pleiades* group.

M. Tempel has made a chart of the *Pleiades*, using the stars in the *Durchmusterung*, on which he has traced the outline of the nebula near *Merope*, as seen by him with a 4-inch telescope with a magnifying power of 24. It appears to have an elliptical form, the greatest and least diameters being about 35′ and 20′. He also remarks that the nebula has been better observed with small telescopes than with large ones, and some doubt has been expressed as to the reality of its variability. If this is the case, it is difficult to explain the apparently decisive observations of M. Wolf, who has examined the spot with the same telescope under equally good atmospheric conditions, when the nebula has been visible at certain times and invisible at others.

Proper Motions of Southern Stars.

The materials available for the determination of the proper motions of stars visible only in the Southern Hemisphere are very scanty; and Mr. Stone, in his paper on the "Proper Motions of 406 Southern Stars," acknowledges the difficulty he has found in obtaining reliable ancient observations suitable for comparison with the places of stars observed at the Cape Observatory since the erection of the Transit-circle. Had Lacaille made his observations of 9,766 stars with so good an instrument as the transit and quadrant of Bradley, the catalogue of stars observed by him, published by the British Association, and reduced to the epoch 1750, would doubtless have formed the same standard basis for the determination of the proper motions of Southern Stars as the *Fundamenta Astronomiæ* has been for the proper motions of stars in the Northern Hemisphere. Of the stars contained in Lacaille's Catalogue, about 398 were observed with his altitude instruments, and Mr. Stone remarks that their resulting places appear to be deserving of every confidence, but of these only about 130 are southern stars not observed by Bradley. The remaining places were determined simply by observing the appearance and disappearance of the stars in the rhomboidal micrometer; and Mr. Stone has found that when the latter places are compared with corresponding places deduced from modern observations, the discordances are in general so large and irregular, that he has been compelled to abandon all hopes of obtaining satisfactory proper motions from

a comparison with Lacaille's observations. For comparison-places he has, therefore, had to rely upon the accurate, but somewhat limited, catalogues of Fallows, Johnson, and Henderson, about the epoch 1830. Use has also been made of an unfinished catalogue deduced from observations made at the Cape Observatory from 1834 to 1840, reduced to the epoch 1840. For the comparisons in N.P.D., Brisbane's Catalogue has likewise been used. The resulting proper motions deduced from comparisons with each of those catalogues is given in Mr. Stone's paper in a tabular form, the adopted values in R.A. and N.P.D. being inserted in the last two columns.

The stars having a proper motion greater than $0^s{\cdot}1$ in R.A., or $1''$ in N.P.D., are the following:—

No. in B.A.C.	Approx. R.A.	Approx. N.P.D.	Proper Motion in R.A.	Proper Motion in N.P.D.
	h m	° ′	s	″
64	0 12	155 41	+0·265	−1·18
88	0 18	168 2	+0·720	−0·32
176	0 33	150 14	+0·125	−0·54
1044	3 14	133 36	+0·266	−0·75
1898	5 48	170 34	...	−1·10
4790	14 23	177 33	−0·160	+0·05
4831-2	14 30	150 15	−0·485	−0·75
6873	19 54	156 31	+0·190	+1·15
7020	20 37	179 28	−0·130	+0·01

Mr. Stone remarks that the large proper motion of B.A.C. 88 in R.A. is confirmed by a comparison with the R.A. in Lacaille's Catalogue.

Struve's Observations of the Double Star Σ 634 = Camelopardali 19 Hev.

M. O. Struve communicated a paper about two years since to the Imperial Academy of St. Petersburg, a copy of which has lately been received by the Society, giving some interesting observations of the stars composing this binary, and the probable conclusion from them. This star is numbered 919 in the *Groombridge Catalogue*, and 1565 in the *B. A. Catalogue*. The two components are of the 4·7 and 7·9 magnitude respectively; their mutual distance at the present time is not more than about $20''$. But when W. Struve in 1827 drew up his *Catalogus novus stellarum duplicium*, this distance amounted to nearly $37''$, which, exceeding the limit adopted in the Catalogue, was the cause that the observations were relegated to a supplement of the *Mensuræ Micrometricæ*, and were afterwards to a great extent overlooked. M. Dembowski, however, during his observations of all the Dorpat

double stars, noticed the great diminution which had taken place in this distance of the components, and M. O. Struve's attention having been called to the subject, he also made a series of observations, commencing in 1868. The general result of all the observations of W. Struve, Dembowski, and O. Struve are well represented by the formulæ:—

Difference of R.A. =

$$-4''{\cdot}120 \pm 0''{\cdot}038 + (0''{\cdot}1523 \pm 0''{\cdot}0024)\,(t - 1850{\cdot}0).$$

Difference of Declination =

$$+28''{\cdot}583 \pm 0''{\cdot}040 - (0''{\cdot}3039 \pm 0''{\cdot}0026)\,(t - 1850{\cdot}0).$$

Some older and less accurate measures were found, made by W. Struve in 1819 with Dollond's transit instrument, at Dorpat, and by Sir J. South in 1825 with his 7-foot equatoreal, at Passy, all of which agree very satisfactorily with the above formulæ. The mean of South's observations gave, for 1825·0, distance $= 37''{\cdot}01$, angle of position $= 346°\ 23'$.

Our late Associate, Professor Argelander, has given in the seventh volume of the *Bonn Observations* the proper motion of the principal star, making use of all observations made since 1790. This amounts annually to $-0^s{\cdot}0365$ in R.A., and $+0''{\cdot}141$ in Declination. By comparing the absolute proper motion of the principal star with the relative motion of the two stars, M. Struve finds that the smaller star moves annually in R.A. $+0^s{\cdot}017$, and in Declination $-0''{\cdot}163$. This amounts to $0''{\cdot}170$ of absolute proper motion in a great circle, whilst that found by Argelander for the bright star is $0''{\cdot}175$, or nearly the same quantity in a precisely opposite direction. Had it been in the same direction, no doubt could reasonably be felt concerning the physical connection of the two stars. But is the reverse a proof that they are not so connected? "Certainly not," says M. Struve; "on the contrary, we seem rather to have here an indication favourable to their connection. In the vast majority of stars the proper motion scarcely amounts to a sensible quantity in centuries. The large proper motion, therefore, of two stars so near each other necessarily suggests the idea of mutual dependence of motion, and this idea is considerably strengthened by the fact that the motions are so nearly in an opposite direction to each other. For this would certainly be the case if the motions of both are produced by their mutual attraction. In this case the nearly equal amount of the apparent motions would indicate that the two stars, although much differing in brightness, were nevertheless nearly equal to each other in mass; unless the centre of gravity of the two have also a considerable proper motion (as is the case in so many double stars), whence it would follow that the ratio of the masses would differ according to the absolute motions of the components thus modified." M. Struve considers that if these be so, we here have to do with a very interesting system, and one probably at a comparatively small

distance from our own. It is therefore important to obtain determination of its annual parallax, for doing which its great northern declination is a very favourable circumstance, as it can be observed above and below the pole during nearly the whole year. Favourable conditions also exist for the determination of relative parallax, as there are several stars from the eighth to the tenth magnitudes within 4′ distance of the pair.

The physical connection of the two stars may be considered as proved when the micrometer-measures show a deviation of the relative motion from a straight line, to determine which the existing observations are not sufficient, especially as there are none at the mean epoch. Perhaps we may have to wait ten or twenty years before the micrometer-measures will furnish satisfactory materials in this respect. Should there be no physica connection between the two stars, they will arrive at a minimum of distance of about 9″·2 in the year 1932. But if there is really an orbital motion, a considerably greater proximity will probably show itself at a decidedly earlier period.

Doberck's New Elements of the Orbits of Binary Stars.

Dr. Doberck has contributed to the Royal Irish Academy a paper on the orbits of the six binary stars: *σ Coronæ*, *τ Ophiuchi*, *γ Leonis*, *ζ Aquarii*, 36 *Andromedæ* and *ι Leonis*. The new elements of these stars have also appeared in the *Monthly Notices;* but in the present discussion of the observations Dr. Doberck has given, in addition, a comparison of the calculated angles of position and distances with those deduced from all the available measures. By following Herschel's method of deduction, an interpolating curve was drawn as nearly as possible through the points indicated by the observations, from which the angles of position and distances in the projected ellipse were deduced for the corresponding epochs by the interpolating curve, by the aid of which the elements were calculated. The comparison seems to show that the observations are in general well represented by using the adopted elements, the residuals being on the whole within a moderate range from the earliest observations by Sir W. Herschel to the latest epochs. The period of *ζ Aquarii* is given as 1578·33 years. In this case, and probably also in others where the period is large, and notwithstanding the agreement of the observed and calculated measures, the elements must only be accepted as approximations, owing to the small portion of the orbit described by the components.

In two other papers, also in the *Transactions* of the Royal Irish Academy, Dr. Doberck discusses the orbits of μ^2 *Boötis*, 44 *Boötis*, *η Cassiopeiæ*, and *μ Draconis*, and deduces new and corrected elements of each star. A comparison is then made of the observed and calculated angles of position and distances, as in the first paper.

Schönfeld's Position-Observations of Nebulæ and Clusters.

In Part II. of the *Mannheim Observations*, published since the last anniversary meeting, Dr. Schönfeld gives a continuation of his valuable work, *Beobachtungen von Nebelflecken und Sternhaufen*; the first portion of which was favourably noticed by our President in his address on the presentation of the Gold Medal of the Society to Professor D'Arrest. The differences of right ascension and declination between the nebulæ and the comparison-stars are given in detail in the first section of the work, the positions of the stars having been determined by Professor Argelander from meridional observations made at the Bonn Observatory. The resulting right ascensions and declinations of the nebulæ and clusters are arranged finally in the form of a catalogue, the places being reduced to the epoch 1865·0, and the precessions computed by Bessel's constants. Several of the objects in the present catalogue have been previously observed by Dr. Schönfeld, and their places are therefore also to be found in the former catalogue. A comparison of the places in both elements is made, not only for the corresponding objects in the two Mannheim catalogues, but also with those in Dr. Schultz's preliminary catalogue of nebulæ (*Monthly Notices*, vol. xxxv., p. 135). The differences are, in general, small, and it is satisfactory to find that the positions of these faint and difficult objects have been so accurately observed. The great value of these observations, and also those of Dr. Schultz, noticed in the last Annual Report, consists in their forming a basis for the future determination of their proper motion. The agreement between the observed places of Schönfeld and Schultz, as shown in the last column of the Mannheim catalogue is a sufficient evidence that these selected nebulæ are capable of being observed with a probable error far less than what was formerly supposed possible. It also shows that the two observers have selected the same portion of the nebula for observation, and that these nebulæ have all a sufficient condensation of light to admit of an accurate bisection.

Dr. Schönfeld commenced his observations in 1860.

Value of the Solar Parallax determined by Observations of Flora.

There will probably be different opinions expressed as to the weight to be attached to a determination of the distance of the Sun by observations of the minor planets; but there can be but one as to the industry and care employed by Dr. Galle in his recent application of those of *Flora* made, at his instance, at a considerable number of Observatories both in the northern and southern hemispheres in the year 1873. He has lately published a complete *résumé* of all the observations. The final

result he obtains for the solar parallax, deduced from 41 northern and 40 southern observations (after rejecting 15 by an ingenious application of Mr. Stone's criterion for the rejection of discordant observations, *Monthly Notices*, vol. xxviii., p. 65) amounts to 8″·873. The northern Observatories taking part in the observations were Bothkamp, Clinton, Dublin, Leipzig, Lund, Moscow, Parsonstown, Washington, and Upsala; the southern were the Cape of Good Hope, Cordoba, and Melbourne.

The Opposition of Mars in 1877.

It is not too early to draw attention to the next opposition of *Mars*, when the more than usual proximity of the planet to the Earth is peculiarly favourable for a determination of the coefficient of solar parallax, either by a co-operative system of meridional observations at the northern and southern Observatories, or by equatoreal observations made according to the method explained by the Astronomer Royal in the *Monthly Notices*, vol. xvii., p. 219, where he has pointed out in detail the many advantages to be derived from adopting the equatoreal method of observation. One of them, and perhaps the most valuable, is that, by a proper combination of observations of *Mars* and neighbouring stars east and west of the meridian, an independent value of the constant of solar parallax may be obtained, by the use of one instrument by one or more observers, without depending on the observations made at any other Observatory. Viewing the importance of an early preparation for the work, the Astronomer Royal, following the plan which he arranged at the opposition of *Mars* in 1862, has again prepared a chart, which is inserted in the November number of the *Monthly Notices*, containing all the available stars in the neighbourhood of *Mars* near the time of opposition in 1877, selected from Weisse's Bessel, *Catalogus Stellarum ex Zonis Regiomontanis*, No. 1, the places being approximately brought up from 1825 to 1877 by the application of $+2^m\,42^s$ to the R.A., and $-17'$ to the N.P.D. The chart is also accompanied by a catalogue giving the approximate R.A. and N.P.D. in a tabular form for the convenience of observers.

As it is fully expected that a very reliable value of the coefficient of solar parallax will be obtained from the observation of *Mars* during this very favourable opposition for the determination of this constant, it is hoped that the equatoreal method will be systematically adopted at Observatories possessed of a good and firmly mounted instrument, especially at those which are favourably situated with respect to the position of *Mars* in the heavens, among which may be classed nearly all our principal colonial Observatories. M. Liais, of Rio Janeiro, has already pro-

mised his co-operation with much better instrumental means than that at his disposal in 1860 and 1862. These extra-meridional comparisons should not, however, interfere with the regular meridional observations of *Mars* and selected stars at the principal northern and southern Observatories, which should have the same, if not greater, attention as at former oppositions.

Relative Brightness of Jupiter's Satellites.

M. Flammarion has lately made an extensive series of comparisons of the relative brightness of the satellites of *Jupiter*, the results of which are given in a tabular form in the *Comptes Rendus* for July 19, 1875. He considers that his observations clearly show that the intrinsic nature of the satellites is not the same, and consequently that their reflecting surfaces are very different. For example, he finds that the fourth satellite is less luminous than the first and third, although it is of greater magnitude, and that its surface is also less brilliant than the third, much more so than could be accounted for from their different magnitudes. This M. Flammarion explains by supposing that the external superficial covering of the fourth satellite is relatively darker than that of the others. From its variable lustre, he is inclined to believe that its variability is not due to permanent spots on its surface, but more probably to some atmospheric phenomena. Its magnitude varies from the sixth to the tenth, the mean being 7·6.

The magnitude of the third satellite has been found to be 5·9. Of the four satellites it is that which is the most constant in its lustre, which may be considered as invariable. M. Flammarion has scarcely been able to notice any difference of lustre between the first and second satellites, but they have both a slight variability. Their mean magnitude is respectively 6·8 and 7·0, and they are very white. The first is, however, of rather greater intensity, and it can be perceived in daylight when the fourth is invisible. The relative lustre is not the same by day and by night, the larger satellites increasing their brightness in the night, on account of the greater extent of their surface. M. Flammarion gives the following as the general results of his observations:—

1. The dimensions of the satellites decrease in the following order: III, IV, I, II. Sometimes the first has appeared smaller than the second.

2. Intrinsic light with equal surfaces: the order is I, II, III, IV. Sometimes the second appears slightly more luminous than the first.

3. The variability of the lustre decreases in the order, IV, I, II, III.

In a subsequent communication, M. Flammarion has given

the results of further observations of the fourth satellite. Comparing each observed magnitude assigned to it with the position the satellite occupied in its orbit at the time of observation, he has found that the smallest magnitudes were observed when the satellite was in the eastern half of its orbit, while the largest generally occur in the western half. From this it is considered that there is some evidence in favour of the hypothesis that this satellite rotates in a similar manner to the Moon, its face being always turned towards *Jupiter*. In this case, the greater and less luminous portions of its hemisphere would be turned towards the Sun when the satellite is respectively in the superior westerly and inferior easterly quarters of its orbit. This hypothesis, however, does not account for all the observed variations of lustre in this satellite which appears to be also subject to atmospheric disturbances which affect its reflective surface.

Abd-al-rahman al-Sûfi's "Description des Étoiles Fixes."

A very interesting and valuable contribution to ancient astronomy has appeared during the past year. It is entitled *Description des Étoiles Fixes, composée au milieu du dixième siècle de notre ère*, by the Persian astronomer Abd-al-rahman al-Sûfi, and is literally translated from two Arabic manuscripts, one preserved in the Royal Library of Copenhagen, and the other in the Imperial Library of St. Petersburg, with Notes, by Dr. Schjellerup, of the Observatory of Copenhagen. The first of these manuscripts is a copy made in 1601, from another directly transcribed from that of Sûfi, and was in the possession of Niebuhr in 1763. After its translation had been completed, M. Dorn, of St. Petersburg, procured for Dr. Schjellerup the second manuscript, which had only been recently acquired by the Imperial Library, and of which M. Dorn had already given a brief description.

The author of this ancient *Uranometria* was born in the year 903 of our era, his name indicating that he belonged to the sect of the Sûfis of Rai, east of Teheran. He appears to have been a man of great natural talent, living at the Court of Schiraz and at Bagdad, where he enjoyed a great reputation for his learning. He was in high favour with the reigning prince, for whose instruction this work on the stars appears to have been written. The descriptions of the stars are founded on Ptolemy; but although his magnitudes generally agree with those of Ptolemy, yet there are sufficient variations to show that Sûfi's magnitudes are not a simple translation from the older work. An inspection of Sûfi's observations soon makes us believe that all the stars have been examined and re-examined with attention, showing how truly [redacted] old astronomer had accomplished his purpose. Dr. Schjellerup [redacted]ks: "One can soon see the vast extent of his works, the

perseverance, the minute exactness, and, above all, the scientific criticism, almost in modern style, with which he has carried on his labours. Taking all into consideration, Sûfi, in his descriptions, has given us the state of the stellar sky in his time, which merits the greatest confidence, surpassing his model, and which, during the succeeding nine centuries, has been without a rival until the appearance of the *Uranometria Nova* of the illustrious Argelander."

Dr. Schjellerup has given, in the introduction to the work, a comparative table of the magnitudes of the principal stars extracted from Ptolemy, Sûfi, and Argelander. This table may be found useful where the larger stars are suspected of variability. This list, in which the ancient and modern estimations of magnitude can be easily compared, will repay a close examination, and it will be soon perceived that while the relative magnitudes occasionally have slight differences, they are on the whole as accordant as could be expected. It may be remarked that Ptolemy's magnitudes are not those which will be found in the *Almagest*, but that they have been taken from Sûfi's work. Dr. Schjellerup considers that in the *Almagest* the magnitudes are very untrustworthy, being expressed in round numbers, and in such confusion that no one can place them in proper order for their identification. There can be but one opinion on the value of Dr. Schjellerup's translation of these Arabic MSS., which forms a most important contribution to astronomical literature, and more especially to the history of stellar astronomy.

Mr. De La Rue's Auxiliary Tables for the Reduction of Solar Photograms.

Mr. De La Rue has had printed for private circulation a set of auxiliary tables for determining the angle of position of the Sun's axis and the latitude and longitude of the Earth referred to the Sun's equator. The calculations were made by Mr. Marth. These tables are employed in the reduction of the ten-year series of solar photograms taken at Kew, and they will be found to be generally applicable in the reduction of photographic observations of the Sun. The following data are given for every ten minutes of the Sun's longitude, arranged in separate columns; the "angle between the circle of declination and the Sun's axis"; the "heliographical latitude of the Earth"; and "reduction of longitude." A supplementary table is also given, containing the correction required to the position-angle to allow for the difference between the true and assumed obliquity of the ecliptic. These auxiliary tables will be of great assistance in the reduction of solar photograms taken at other Observatories than at Kew.

quite exceptional. Indeed, it seemed to me that the general atmospheric definition was decidedly better than I had been accustomed to see it with smaller instruments. This may be partly due to the construction of the dome, in which the arrangements for securing equality of internal and external temperature are, I believe, nearly unique."

Measures of the distances and position-angles of *Ariel*, *Umbriel*, *Titania*, and *Oberon* were made in the springs of 1874 and 1875, on 8, 10, 34, and 32 days respectively. The resulting distances and position-angles are given in tabular form, together with the corresponding numbers derived from Von Asten's Elements, III. The satellite of *Neptune* was observed on 24 days, from November 1873 to February 1874. Professor Newcomb gives a very complete and detailed discussion of the observations, and finally deduces new elements of the orbits of the satellites, and new values of the masses of *Uranus* and *Neptune*. With regard to *Ariel* and *Umbriel*, no sensible correction appears to be required to be applied to the provisional mean motions deduced from the Malta observations, and they will probably still suffice for the identification of these objects during several centuries.

The following remarks on the magnitude of the inner satellites, and on the possibility of additional satellites of *Uranus*, will be read with interest. "The greater proximity of the inner satellites to the planet makes it difficult to compare them photometrically with the outer ones, as actual feebleness of light cannot be distinguished from difficulty of seeing arising from the proximity of the planet. However, that *Umbriel* is intrinsically fainter than *Titania* is evinced by the fact that, although the least distance of the latter is somewhat less than the greatest distance of the former, there is never any difficulty in seeing it in that position. From their relative aspects in these respective positions, I judge *Umbriel* to be about half as bright as *Titania*. *Ariel* must be brighter than *Umbriel*, because I have never seen the latter unless it was farther from the planet than the former at its maximum distance. Three or four years hence, when the orbits are so far closed up that *Oberon* and *Titania* pass within 15″ of the planet, it will be possible to compare them directly with *Ariel* at equal distance; but at present no reliable estimate of their relative magnitudes can be made.

"No systematic search for new satellites of this planet was entered upon, partly because the season in which *Uranus* is in opposition is now an unfavourable one for prosecuting such a search, and partly because the attempt would have absorbed so much of the observer's time and energies as to detract from the excellence of the micrometer-observations. When faint objects, which might have been new satellites, were seen around the planet, their positions relative to the latter were noted; but in no instance was any such object found to accompany the planet. I think I may say, with considerable certainty, that there is no

satellite within 2′ of the planet, and outside of *Oberon*, having one-third the brilliancy of the latter; and therefore that none of Sir William Herschel's supposed outer satellites can have any real existence. The distances of the four known satellites increase in so regular a way that it can hardly be supposed that any others exist between them. Of what may be inside of *Ariel* it is impossible to speak with certainty, since, in the state of atmosphere which prevails during our winter, all the satellites would disappear at 10″ distance from the planet."

From a consideration of all the results derived from his observations, Professor Newcomb concludes that we may assume the most probable value of the mass of *Uranus* to be $\frac{1}{22800}$, and that the probable error of the denominator may be estimated at 100. In like manner the mass of *Neptune* deduced from the measures of the satellite is $\frac{1}{19380}$, with a probable error in the denominator of 70. He is inclined to prefer this value to that deduced by him from the perturbations of *Uranus*, $\frac{1}{19700}$; but astronomically this difference—one-sixtieth of the mass of the planet—is not of much importance, except in computing the perturbations of Uranus.

During July 1874, under the finest atmospheric conditions, a search was made on several occasions for a second satellite of Neptune, but without success.

The following elements are those deduced by Professor Newcomb as his definitive results. The elements of the most probable mean plane of the orbits of the satellites of *Uranus* are:—

Ascending node on Earth's equator	$165^\circ\cdot10 + 1^\circ\cdot43\,(T-1850)$
Inclination	$75^\circ\cdot14 - 0^\circ\cdot14\,(T-1850)$

The corresponding elements referred to the ecliptic are:—

Ascending node	$165^\circ\cdot48 + 1^\circ\cdot40\ \ (T-1850)$
Inclination	$97^\circ\cdot85 - 0^\circ\cdot013\,(T-1850)$

Other elements of the satellites of *Uranus* are:—

	Mean Longitude. Epoch: 1871, Dec. 31, W.M.T.	Radius of Orbit.	Period of Revolution. days.
	°	″	
Ariel	21·83	13·78	2·52038
Umbriel	136·52	19·20	4·14418
Titania	229·93	31·48	8·70590
Oberon	154·83	42·10	13·46327

The following are the definitive elements of the satellite of *Neptune*:—

Radius of orbit	16″·275
Mean longitude	98°·96

Node on equator	183°·03
Inclination	121°·70
Daily motion	61°·25679
Period of revolution	5·8769 days

Epoch: 1874, Jan. 0·0, Washington mean time.

Professor Newcomb expresses an opinion that, where any difficulty has been found in seeing *Titania* and *Oberon*, he should not hesitate to pronounce it impossible to see the two inner satellites, and he thinks that some small objects observed at Bothkamp for *Ariel* and *Umbriel* cannot be these satellites. There is, therefore, every reason to believe that they have only been recognised through the great Washington equatoreal and the Malta reflectors, and that their discovery is, therefore, due to Mr. Lassell, to whom, we are glad to notice, it is distinctly assigned by Professor Newcomb.

The observations of the satellites of *Uranus* and *Neptune* were continued at Washington in the spring of 1875.

Le Verrier's Planetary Researches.

Although our President will describe to the meeting the principal historical and mathematical details connected with the planetary researches of M. Le Verrier, including the state of his investigations at the present time, still the Council are desirous to offer in this section of their Report their special and sincere congratulations to their illustrious Associate at the proximate completion of the herculean labour on which he has been so many years employed, and for which the gold medal of the Society has been awarded to him a second time by an unanimous vote. M. Le Verrier's theoretical investigations of the motions of all the primary planets have now been presented to the Académie des Sciences: first, of the inner series of planets from *Mercury* to *Mars*; and, more recently, of the outer series from *Jupiter* to *Neptune*. Tables also have been constructed for all, excepting the two outermost planets; those from *Mercury* to *Jupiter* having been published, while those for *Saturn* are ready for the printer, if not already in the printer's hands. In the meantime, through the kindness of M. Le Verrier, it is expected that the tabular places of *Saturn* for 1880, deduced from the new tables, will be privately furnished to the Superintendent of the *Nautical Almanac*, in anticipation of their publication, so that they may be incorporated in the *Nautical Almanac* for that year. When the new tables of *Uranus* and *Neptune* are constructed, astronomers will have the full practical benefit of one of the greatest mathematical contributions to astronomy of modern times.

satisfying less doubtfully the theoretical conditions. A table of the theoretical star showers assignable to other comets, periodic and non-recurring, which either passed or may hereafter return in their orbits to points of passage at no great distance from the Earth's track, and along whose cosmical paths, according to different views which may be held of the common origin of comets and meteor showers, streams of cometoids of unknown length, producing meteor showers, may accordingly be supposed to be collected, is included in the same report. A supplementary table to the previous year's "General List of Meteor Showers," compiled by Mr. Greg (in extension and corroboration of that list) from one or two thousand recent meteor observations furnished by the Luminous Meteor Committee of the British Association, the Radcliffe observations, and other sources, is also there given, and supplies, with the previous year's list, a useful reference to all the recorded descriptions by different observers of the appearances of meteor showers which have hitherto been published. The system of grouping together meteor showers, or radiant-points, in restricted groups or regions adopted in Mr. Greg's general catalogue somewhat resembles the description of the fixed stars (whose number as ordinarily visible that of the known meteor showers bids fair at no very distant period to attain) by their constellations; but in its object the plan of its construction is less artificial; and almost countless as the number of variously recorded meteor showers may ultimately become, their collection into separate groups extending over some successive days or weeks is the only means to combine together observations which are themselves either not more accurately limited in position and duration, or, from their close resemblances to others (it may be similarly indistinct) have every appearance of relating actually and independently to the same meteor shower. The discrepancies of observations that are unavoidable (as was evident in those of the Biela star shower of November 1872, and as constantly happens in simultaneous watches for the radiant point of the Perseïd shower in August) makes it useful to keep in view together individual observations, which may ultimately serve the important purpose of separating meteor showers into those which are most frequently and most abundantly, and those which are but slightly observed, or whose apparition may even be so exceptional as only to be recorded in a solitary case. As accumulations of repeated observations of single meteor showers, it is probable that the radiant regions of Greg's general list are in most of its principal and best marked showers correct; and, for the use of observers to whom this provisional stage of comparison of new with older observations is valuable, it supplies a very large, complete, and—from the care with which it has been constructed—thoroughly trustworthy store of information. The Luminous Meteor Committee of the British Association are now preparing for distribution a complete col-

lection of all the original observers', and the latest compilation of Mr. Greg's general list of meteor showers,—a work which, with great care and distinctness, Mr. Greg has illustrated with a map, on the scale of Captain Tupman's projection, of all the general radiant-points, and many of the subordinate outliers, or juxta-central positions embodied in his list. A system of regular recourse to, and of constant improvements of this map by continued observations, and—should they present themselves distinctly enough to be detected—by noting the occasional appearances of new meteor showers in the atmosphere, is still, as it has been hitherto, the chief object which the Luminous Meteor Committee are endeavouring to pursue.

Accounts of recent falls of several Aërolites may be added to the rather scanty number of similar announcements made last year. The large fireball seen near Mooltan at daybreak on September 23, 1873, was aërolitic. Several stones of the ordinary sizes and descriptions fell on a large area on each bank of the Sutlej, near Khairpur. Six aërolites have been found, weighing together about 30 lbs., and the specimens have been deposited, for the most part, in Indian museums. Another recent aërolitic fall is that of Castalia, North Carolina, U.S., May 14, 1874, an examination of which has been made by Dr. J. Lawrence Smith. A large proportion of nickel iron in the metallic state (15 per cent.) is contained in these stones; but their specific gravity is yet not great (2·66) for aërolites, and their mineral composition is that of an ordinary aërolitic type. Three stones, weighing together about 16 lbs. were found on an area of descent several miles in length and breadth, and the meteor that attended the stonefall was visible in daylight ($2^h\ 30^m$ P.M.), and was followed by a series of explosions. Falls of aërolites also took place on the 12th of February and the 31st of March last year, which were of considerable magnitude and interest; the first in the neighbourhood of Iowa, U.S., and the second at Zsadany, a village in the south-eastern Danubian Province of Hungary, the Banat. They were not alike in weight, the former having yielded fragments of 43, 20, and 16 lbs. in weight (with a total aggregate of, perhaps, 300 lbs.), while the largest aërolite of the latter fall weighed less than half a pound, all the fragments of it discovered scarcely weighing together a full pound. It is on the meteorites of the former of these two falls that some important experiments were immediately made by Dr. A. Wright, who had applied both the air-pump and the spectroscope to examine the gases occluded in certain hitherto untested meteoric irons with very satisfactory results. The meteoric irons of Red River (Texas), Arva (Hungary), and Dickson County, Tennessee (the last of which fell in 1835) all yielded a much larger proportion of hydrogen by exhaustion in the cold, than of carbon gases, the latter, however, reaching a considerable percentage at a full red heat. In 44 times its volume of gas extracted from the hard and pulverised carboniferous Arva iron 3 or

4 per cent. only of carbonic acid gas was found*; but, as compared with the iron disseminated through rocky aërolites, the following percentage quantities extracted from a siderite (the Dickson County iron) and iron picked out from the Iowa aërolite will show the relatively greater quantity of carbon gases contained in stony above that occluded in iron meteorites. Proportions of these gases and of hydrogen are also added, which the pulverised stone of the Iowa meteorites evolved at a low and at a high temperature respectively, showing that carbon gases are not only most abundantly present in stony aërolites, but that they are given off more readily than hydrogen at low temperatures, while hydrogen is yielded by the iron which they contain chiefly at the highest temperature to which they were submitted. The total amount of gas extracted from the Iowa aërolite was about two-and-a-half times its volume, and about twenty times that of the iron included in it.

	Carbon dioxide.	Carbon oxide.	Hydrogen.	Total.
Gases extracted from the Siderite of Dickson County, Tenn., U.S.	15·3	13·3	71·4	100
Do. from picked iron of aërolites of Iowa, U.S.	35	14	49	98
Do. at 100° C. from Iowa aërolite	95·46	0·0?	4·54	100
Do. at 250° C. „ „ „	92·32	1·82	5·86	100
Do. at full red heat from do.	5·56	0·0	87·53 Nitrogen calc. 6·91	100

The relative abundance of carbon gases in stony aërolites and the ready evolution of these gases from them at a moderate heat distinguishes these bodies from siderites, or iron meteorites, and the analogy which presents itself with the results of spectroscopic observations of comets, in which the lines of the carbon spectrum are the most conspicuous, suggests a similarity of origin, and of structure and composition of the materials of comets to the stony matter enclosing disseminated iron met with in the rocklike substance of ordinary meteorites. Papers full of interest and instruction on the present stage of progress of our knowledge regarding the native history and the characteristic features of meteorites (to which reference is made below†)

* Mallet's examination of the Augusta County iron showed, however, nearly equal quantities of the gases hydrogen and carbonic oxide to be present in that siderite. At temperatures different from those in the above Table, the Iowa aërolite gave off carbonic oxide more abundantly than the Table shows, 5 or 6 per cent. being extracted at a temperature a little above 250° C.

† *Some Lecture-Notes upon Meteorites*, by Prof. N. S. Maskelyne. *Nature*, vol. xii., pp. 485, 504, 520.—The present "Catalogue of the collection of meteorites exhibited in the British Museum," published by Prof. Maskelyne (November 1875), describes specimens in its possession of 307 different meteorites, of which nearly 200 were seen to fall. Specimens of the above aërolites of the past year, and of the remarkable masses of iron found at Ovifak, Greenland, are recent important additions to the collection. A valuable series of

have, during the past year, been made, notably by Professor Maskelyne and Dr. Tschermak, for a fair appreciation of the value of which the originals should be perused. The prevailing mineralogical features of aërolites are described and explained at length in Professor Maskelyne's papers; while evidence of a view of their production is collected and applied with equal clearness by Dr. Tschermak that these bodies are a species of tufaceous rock consolidated in and projected from certain volcanic fissures or craters of explosion too small to furnish streams of molten lava, and it may perhaps be added, to project very mighty fragments, although yet, from the finely crushed, worn, and rounded grains of which aërolites are compacted, evidently volcanic vents of by no means insignificant activity, and subject, it would seem, occasionally to pretty violent eruptions.

To this review of aërolites it may be added that a description of a meteorite resembling iron, but of less specific gravity, by a witness of its fall was received by the Astronomer Royal, Sir G. Airy, which is said to have fallen on the 4th of October last at Peterhead, in Scotland; but the alleged meteorite, since its receipt and examination by Professor Maskelyne, has been shown to be a piece of artificial furnace slag, and no further testimony of a concomitant fireball of unusual size has been received.

But few detonating meteors have been visible during the past year; the only fireballs which were probably of this description having been that of the 10th of February 1875, observed in Paris and at a great many places in France, the streak of which assumed a serpentine form and remained visible for half-an-hour, and a large fireball, asserted to have been aërolitic, which passed over Victoria, West Australia, in the night of the 13th–14th of April last, and was visible over a wide extent of the adjacent country.* Large meteors were seen in England on the 1st of September 1874, on September 16, October 11, and December 17, in the same year, the last being visible in the south at $10^h\ 30^m$, while a large meteor is said to have been seen at Paris at about 10 o'clock P.M. on the same date. A bright meteor seen at Bristol and at Cooper's Hill in Kent at 8^h P.M. on the 9th of March last was probably also seen at Orleans in France,† where an aërolite is said to have descended in the

"Chapters in the History of Aërolites," by Prof. Maskelyne's Assistant, Dr. W. Flight, published in the *Geological Magazine* of last year (1875), forms an able continuation to the present time of the works of Buchner, Haidinger, and Rammelsberg (hitherto the only Memoirs treating of the subject), noting both the progress of research and the contemporaneous records and descriptions of new falls of meteorites since the year 1869, when the last of the formerly conducted summaries by those earlier authors had appeared.—*Die Bildung der Meteoriten, und der Vulkanismus*, by Dr. G. Tschermak. Vienna Academy *Sitzungs-Berichte*, 1875, Pt. II.

* The fireball of September 7, 1875, was also accompanied by a detonation, heard near Chelmsford, immediately under its point of disappearance; and that of the 14th of last September also detonated, as will shortly be described.

† *Nature*, vol. xi., p. 396.

streets. The real course of the fireball, from the two English observations of its appearance, was from about 80 miles over the neighbourhood of Alençon (Orne), to 15 or 20 miles over the neighbourhood of Blois, about 30 miles S.W. from Orleans, where its near approach to the Earth may have caused sounds of its explosion to be heard. On the 12th of April a meteor brighter than *Venus* was observed at Birmingham, which may also have been identical with fireballs of great size observed on the same date in France, at Havre and in Paris. The meteor passed at 8^h 6^m P.M. from λ Coronæ to γ Serpentis, down the eastern sky. Other large meteors, exceedingly brilliant, of the past year appeared on the 16th and 17th of March, 22nd of April and 2nd of May, and on the 3rd, 7th, and 14th of September.* The last great fireball was seen in the daytime and in sunshine at about 1^h 40^m P.M. on the 22nd of December last. The real paths and heights of each of the last four of these large meteors has been more or less accurately ascertained, many excellent descriptions, especially of the fireball of September 14, having been collected and compared for this purpose by Captain Tupman, who himself observed two of the large meteors, and has obtained from the observations the following very reliable determinations.

* A single notice has also been received of a large fireball which passed over the north of Scotland in the night of October 28, 1875, like a huge star, large enough to look like a balloon, and dropping thousands of sparks as it went. (Account of its appearance near Aberdeen.)

Heights and Real Paths of Large September Meteors. By Captain Tupman.

1875.	G.M.T. h m s	Weight or Degree of Accuracy.	Radiant-point. R.A. °	Decl. °	Height and Position of Real Path at First Appearance. (Statute Miles).	Disappearance.	Velocity. (Statute Miles per Second).	Nearest known Meteor Radiant-point.
Sept. 3	9 52 0 P.M.	From 3 accordant observations.	311 (near χ *Cephei*)	+52	Fell vertically from 75 to 40 ($\pm$1) miles above a point 15 miles S.E. from Selsey Bill (in the English Channel), 50° 31′ N., 0° 35′ W.		27 (34 miles in 1¼ second).	S. & Z. 146, Sept. 5, 321° + 60°
Sept. 7	11 21 0 P.M.	From 6 accordant and 2 discordant observations.	344 (near α *Pegasi*) [A second independent reduction gave (347°, + 15°) $\pm$ 3°	+14	69 miles over 51° 13′ N., 0° 50′ E. (near Ashford, Kent).	21 miles over 51° 47′ N., 0° 36′ E. (near Witham, Essex).	15 (average of 3 rough approximations).	Tupman 73, Sept. 7–15, 345° + 13°; Heis, T_2 Sept. 1–15, 343° + 10°.
Sept. 14	8 27 30 P.M.	From 12 (8 of which are good) accordant observations.	348 (near γ *Piscium*).	0 $\pm$ 3	52 miles, nearly over Horncastle, Lincolnshire.	13 miles, over Hebden Moor, West Riding, Yorkshire.	13 (by mean of 8 estimations).	Schmidt, Sept. 3–14, 346° + 3°.

Of these three large meteors the first and last were of exceeding brilliancy, casting a light quite equal to or exceeding that of the full Moon, which was shining, when the last appeared, brightly enough to make the stars of *Ursa Major*, near which its course was seen at Bridport, in Dorset, look faint near the northern horizon; while, to an observer near Carlisle, the Moon, near which it appeared, looked pale beside it. At St. Ives, Hunts, the shadows which it cast, though thrown in an opposite direction, were quite as distinct as, and even stronger than, those proceeding from the Moon. Owing to the general clearness of the sky on the night of the 14th, many similar descriptions of the meteor were recorded, and the above path was deduced from an unusual number of excellently accordant observations.* No separation into fragments occurred at their extinction, and the trains of sparks which accompanied these large meteors in their flight scarcely presented any appearance of a persistent light streak on their track. The meteor of September 7, although less luminous generally than the other two, yet lit up all objects brilliantly at Chelmsford, Essex, vertically below its point of explosion and disappearance, and a double report, followed for fifteen seconds by a sound like distant thunder, was there heard by Mr. H. Corder $1^m\ 45^s$ after its disappearance—an interval corresponding exactly to its calculated height at the point of its extinction. Bolides of considerable size, obscured by clouds, were seen on September 2 and 5, and a companion bolis of the great fireball of the 14th of September was observed to precede it at Lynn about five minutes in time, on a course from the same radiant point, at no great elevation above the eastern horizon. The last large fireball of the year, which appeared at about $1^h\ 40^m$ P.M. on the 22nd of December last, among the places at which it was observed, was described at Hay, South Wales, by the Rev. T. W. Webb, and by Mr. E. Daw, at Brangling, near Ware, in Herts. The course of this daylight meteor appears to have been from about forty-five miles above the southern part of Warwickshire to about fifteen miles above the centre of Northamptonshire, disappearing about 50 miles from Mr. Daw's position in Herts, where he was unable to distinguish any sound of its explosion. The direction of its flight was from a radiant point at about R.A. 250°, N. Decl. 20°, near β *Herculis*, distant about 45° from the Sun's apparent place.

A collection of eight duplicate observations of bright shooting stars, chiefly Perseïds, during the shower of August 10, 1874, was presented in the last Report of the Luminous Meteor Committee to the British Association, from which the following average heights and velocities (in statute miles) have been ob-

* By Mr. Burman's description at Wath, the meteor detonated; sounds like cannon and thunder succeeding it at an interval of $3^m\ 37^s$, which agrees exactly with the distance of Wath from the end point of its course. Both of the large meteors of September 3 and 7 were seen and noted at Oxford, by the Rev. R. Main's assistants at the Radcliffe Observatory.

tained: at first appearance 84 miles; at disappearance 55 miles; average velocity from five observations of duration (four Perseïds or Cassiopeïds, and one Polarid) 31·5 miles per second. A bolis rather brighter than *Venus* was simultaneously observed during this shower with considerable accuracy at Birmingham and Newcastle-on-Tyne, proceeding with sparks and an explosion and with a slight persistent streak, from the direction of a southern radiant-point. The position of the latter was near μ, ϵ *Aquarii*, at R.A. 313°, S. Decl. 14°, the nearest known radiant-point to which is one in Tupman's list (No. 44, July 28, 326°–13°), corroborated closely in the last six days of July, but more distantly in August, by Dr. Schmidt. The meteor passed from 65 miles over a point in Caermarthenshire to 33 miles over Bangor, in Wales, with a course of 85 miles in a time reckoned as nearly 3 seconds at Newcastle, and about 6 seconds at Birmingham; and the mean resulting velocity is about 19 miles per second. Should this fireball and the three September fireballs above described have been moving round the Sun in parabolic orbits, their observed velocities should all lie between 17 and 19 miles per second, and the greatest departures from this value are those of the two large fireballs of September 3 and 14, the velocity of the first of which depends upon only a single observation of duration, while the mean observed velocity of the last is only 13 instead of nearly 19 miles per second. The uncertainties, both of the lengths of path and of the observations of duration, must, it may fairly be concluded, have been exceedingly prejudicial to the accuracy of the speed determinations.

No reappearance of the April star shower, and none of those of October, November, or December have this year been recorded, the absence of meteors on the periodic nights, and on those about the 2nd of January 1876, having been, as far as cloud and haze permitted observations to be made, particularly marked. The return of the Perseïds in August 1875 was also less conspicuous than in the few immediately preceding years, but it was yet a bright display, and where the clearness of the sky was exceptionally favourable for its observation, good lists of tracks of the meteors were recorded. The hourly numbers observed by Mr. Wood, at Birmingham, with a clear sky on the night of the 10th, were 20 in the first and 40 in the second hour between 10^h and 12^h P.M. The radiant-point was found to be at R.A. 36°, N. Decl. 57°, and this is also sensibly its position as found from the courses of about 20 Perseïds mapped in the same interval at Sunderland by Mr. Backhouse. Some bright meteors of this shower, one more brilliant than *Venus* at 13^h 24^m, at Sunderland, were recorded in this watch. Between 10^h and 12^h P.M. on the 9th Mr. Waller noted the paths of 50 meteors at Birmingham; and from 12^h to 12^h 30^m on the night of the 11th ten meteors, chiefly Perseïds were seen and their courses mapped by Mr. Greg. From these accounts it appears that the intensity of the shower on the nights of the 9th, 10th, and 11th was nearly the same, and that in

frequency the Perseïds last year presented a fair average display. Similar accounts of the shower are given by Mr. Ryves, at Cheadle,* and an interesting summary of observations relating to it at the Royal Observatory of Brussels and at other places in Belgium (with results closely resembling the above) is given in a communication to the Royal Academy of Sciences of Belgium, by Mr. Ernest Quetelet. The shower, Mr. Quetelet observes, was somewhat more remarkable in the south of Europe, and great numbers of the August meteors were counted in France and Italy. Accounts of their appearance at Lisbon, Toulouse, Dijon, Palermo, &c. were published by M. Le Verrier in the *Comptes Rendus*.

At Stonyhurst Observatory the watch for meteors on the nights of the 11th-15th of November was partially interrupted by a cloudy sky on the 12th and 13th, but was unimpeded for several hours on each of the other nights. Nine meteors only were observed during the morning hours of November 12th, of which two were Leonids; and 24 meteors during the night of the 14th–15th, of which ten or eleven were Leonids. As far as can be gathered from this well-sustained watch for their appearance, the shower arising from the principal cluster of the Leonids may thus be regarded as having ceased, and, until the end of another cycle of its returns, to have now almost entirely become extinct.

But a minor cluster of this meteor-ring has quite recently been shown by Prof. Kirkwood to exist, preceding the principal one about twelve years in its arrival; so that, should the correctness of this well-founded conjecture be verified by the event, considerable reappearances of the Leonids may again be expected to be visible about ten years from the present time, on about November 14–15, 1886–88.†

Observations of shooting stars at the Radcliffe Observatory, Oxford, were recorded last year with the same regularity as in former years, and upwards of 150 meteor-tracks observed in 1875, with notes descriptive of their appearance, were separately published in anticipation of the volume of *Astronomical Observations* for 1873, to which they have since been appended. The continuance

* *Astronomical Register*, 1875, p. 222.

† *Nature*, June 3, 1875; and vol. xi., p. 407 (March 25, 1875).—In connection with the extent and distribution of the meteor-clusters known to move in the orbits of certain periodic comets, the positions of Biela's Comet at the times of the appearances of the well-known Biela Comet star-showers of December 6–7, 1798 and 1838, and November 27, 1872, have also been computed by Prof. Newton, with the result that in the two former years the showers were encountered about 200,000,000 and 300,000,000 miles *in advance of*, and in the latter year about 200,000,000 miles *behind* the real position of the comet in its orbit; so that the probable extent of the meteor-cluster with which the Earth is liable to come in contact reaches a length of about 500,000,000 of miles along the comet's orbit. The small comet observed in November and December 1872, by Mr. Pogson at Madras has been shown by Prof. Bruhns, of Leipzig, to have moved apparently in an orbit irreconcilable with that of the system of the Andromedes, and to have been very probably a new comet, wholly unconnected with the Biela group. (*Ast. Nach.* No. 2054.)

of this catalogue is already of the most important value, and it cannot fail, as it is now conducted, to be consulted hereafter as an essential adjunct to all researches and investigations relating to the physical phenomena of meteors and of meteor showers. A similar course to that adopted by the Radcliffe Observatory, it cannot be doubted, will be recognised by the new University Observatory at Oxford for Physical Astronomy as coming from its connection with the University which eminently assisted this branch of observations in its first inceptive stages, under its special care; and the preservation of such systematic records, even of the most transient notes of the observations of shooting stars, it may be hoped, will in time be regarded as an object befitting the consideration, and not undeserving, from well-appointed astronomical observatories, of such occasional attention and vigilance of their observers as they may find it compatible with the duties and with the regular prosecution of their most important standard observations to bestow.

*List of Theoretical Meteor Showers of certain Comets, approximately corroborated by Observations.**

Ref. No.	Comet, and its Node (or Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ⊙ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
1	1746 ☋	Jan. 16	(+0·07)	60	+40	?' (?)
	,, ☌(☋)	Feb. 25 (+11)	−0·03	33(−3)	+33(−5)	(?) (?)
			(−0·01)			
	1231 (☋)	Mar. 10	(+0·06)	32	+31	
2	1833 (☋) ☌	Feb. 12 (−16)	−0·21	144(−9)	+24(+1)	BC? (?)
			(+0·04)			

* *Explanation of the Table.*—The list of accordances is obtained from a comparison of the orbits of 143 comets that appear to have approached within certain limits from the Earth's orbit (including for comparison, where orbits appear to resemble each other, a few cases of more distant passages) with published lists of about 800 observed meteor showers. With the exception of some comets apparently belonging to the meteor shower of the Perseïds (No. 26) the four well-known comet-meteor showers of April, August, and November are not included in the list, and two close comet-shower accordances on the 11th of April and 12th of August would not, but for their early identifications by Weiss and Schiaparelli, have been here introduced on account of the Earth's very distant passages from those comets' orbits. Where the orbit of a zodiacal comet approaches the Earth's path most nearly at a point near to, but not coincident with, the line of nodes, the usual sign for the node (☊ or ☋) is replaced by the Greek letter Omega (erect or inverted) to represent the "appulse", in column 2. The distance of the comet's orbit from the Earth's is reckoned *plus* outwards (and northwards,) and *minus* inwards (and southwards) from the Earth's path at the point of the node or appulse in column 3, and distances measured northwards and

Ref. No.	Comet, and its Node (or Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ☉ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
3	1699 I ☌	Feb. 14	+0·12	266	+ 9	*b*
	(1799 II ☌	„ 15	−0·28	264	+17	
	1858 IV ☌	„ 13	−0·05	272	+12)	
4	1797 ☌	Feb. 18	+0·27	211	+ 9	B, (?)
5	1596 ☌	Feb. 23	+1·4	285	− 8	B″
	(1845 III ☌	„ 26	+0·06	283	− 4)	
6	1864 V ☌	Mar. 1	+0·11	250	−12	{C, *a'*} *c*, C′
	1862 IV ☌	„ 16	−0·01	250	+ 1	
7	1590 ☌	Mar. 8	−0·30	275	−38	*c*
8	(1845 I ☌	Feb. 25	+0·23	309	+25)	
	1763 ☌	Mar. 18	+0·02	312	+21	(*c*)
9	1683 ☌	Mar. 16	+0·03	207	−48	(C) (*c*)
10	1556 ☌	Mar. 19	+0·20	179	−26	(B)
	1264 ☌	„ 25	−0·02	182	−28	
11	1847 I ☌	Apr. 11	−0·95	231	+27	A A′ B″ (B) (*c*) (*b*)
12	1743 II ☌	Mar. 26	−0·30	296	+ 1	{(C) (C)} {B′ *b*′ *b* B}
	1844 II ☌	Apr. 21	−0·08	288	+ 5	
13	1853 II ☌	May 1	−0·07	296	+13	
14	1830 I ☌	Apr. 15	−0·08	116	−36	(B)
15	178 ☌	Apr. 23	+0·22	203	−32	(B)

southwards at the latter point are enclosed in brackets. Variations of the comet-shower co-ordinates in time and place corresponding to the latter point are also annexed to them in brackets, and their signs are to be interpreted like those of ordinary co-ordinates, algebraically.

In expressing the degrees of approximation of the accordances of the meteor showers (to enumerate which in detail would occupy much space) a notation is adopted to show at once the distance of the shower in time and in position from the theoretical or cometary radiant-point; thus A*a*, B*b*, C*c*, represent distances not exceeding 3°6°, 9°12°, 15°18° respectively; and the coincidence is within 3 days if no other mark is added to the letter; a *comma* added to the letter *below* implies that the coincidence is within 6 days. Shower-distances accented thus *a' a' a'' a'''* coincide with the cometary date within 9 12, 15 18 days respectively; a *semicolon* after a letter indicates that the discrepancy is between 18 and 24 days, beyond which limits no connection with the cometary shower can be suspected. A sign of interrogation represents similarly a shower-distance between 18° and 24° from the cometary shower, which may be regarded as the utmost limits to which errors of observation and other uncertainties of the correspondences can be admitted to extend. Within these limits all the recorded showers that present sufficient resemblances to theoretical ones of any of the 143 comets, are included in the list.

Ref. No.	Comet; and its Node (or Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ☉ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
16	837 I ☊	May 1	+0·03	334	−16	C
	(1835 III ☋	„ 4	(−0·06)	337	0)	*b*
17	1737 I (☊) ☊	May 8 (−26)	−0·48	235 (−20)	−15 (−13)	(*b*) (*c*)?
			(−0·13)			
18	1618 III ☌	June 10	+0·10	273	0	(B) (*b*) (C)
19	1781 I ☌	June 14	−0·19	338	+57	(C)
20	1850 I ☌	June 24	+0·06	312	+61	(A) (B')
21	1864 II (☋) ☌	June 27 (−7)	−0·05	12 (−4)	+ 6 (−1)	(A) (B) (C)?
			(0·00)			
22	(1822 IV ☌	June 25	+0·14	348	+28)	*a* (*a*) (*b*)
	1822 III ☌	„ 30	+0·11	342	+14	B'' (*b*)
23	1770 II ☌	July 13	−0·09	349	+12	*b* (C)
24	1770 I ☋	July 8	+0·02	276	−21	*b*
	„ „ ☌	Aug. 6	−0·22	283	−20	(*a*,) (*b*,) (*b*)
25	1737 II ☌	July 29	−0·03	175	+71	(*b*) *c* (?)
26	568 (☊) ☊	Aug. 5 (−13)	−0·06	259 (+3)	−36 (+3)	(B) (*b*) (C) (*c*,)
			(−0·01)			
27	(770 ☌	July 8	+0·20	39	+45	(? Comets of
	1764 ☌	„ 25	−0·11	49	+45)	the "Perseids")
	1870 I. ☌	Aug. 12	+0·01	43	+53	A A
28	1853 III ☌	Aug. 12	−0·69	299	+80	A' *a'* B *b c* (B) (B)
29	1852 II. ☊	„ 10	+0·01	41	−13	(*c*)
	1827 II ☊	„ 11	−0·16	48	− 8	(*b*) *b'* (*c*)
30	1862 II (☋) ☌	„ 19 (−12)	+0·03	47 (−6)	+13 (−2)	(C) (C) (C)
			(−0·02)			B B *b c*
31	1780 II ☌	„ 14	−0·18	3	+38	(*a*) *b* (*b*) B''' C' C'
32	1808 II ☊	„ 16	+0·07	89	+ 6	?" (Sept. showers)
	1797 ☊	„ 23	−0·09	92	0	*c'*

Meteor showers recorded in the catalogues as of considerable duration are enclosed within brackets, thus (A), if the duration exceeds six days; and in noting their approximations in time to the cometary showers the nearest available day of their durations (which often *include* the day of the comet shower) is used.

Although the importance of each accordance is thus only very roughly shown, an estimate of the general amount of correspondence between meteor and cometary orbits can perhaps be gathered from the table, with which view, and to serve as a guide for future observations, and perhaps for more abundant confirmations of the theoretical comet showers, the list has been constructed.

Ref. No.	Comet, and its Node (or (Appulse).	Theoretical Shower day (1875).	Approach of Comet to ⊕'s Orbit (⊕'s Distance from ☉ = 1).	Position of Theoretical Radiant Point (1875). R.A.	Decl.	Degree of Proximity of Observed Meteor Showers.
				°	°	
33	1596 ☊	Aug. 27	−0·25	49	− 9	C, (C) (B)
	1845 III ☊	„ 31	−0·36	47	− 6	
	1854 IV ☊	Sept. 10	+0·02	53	−16	
34	1864 II ☋	„ 2	(+0·03)	57	+ 1	A′ (A) (B)
35	1558 (☋) ♂	Aug. 29 (−4)	−0·42	70	−21	(*a*)
	961 (☋) ♂	Sept. 27 (−14)	−0·03	62	−13	(B) *b* ?
36	1769 ♂ (☋)	Sept. 19 (+9)	+0·78 (−0·02)	17 (+7)	+18 (−1)	(A′) (B′)
37	(1683 ♂	Sept. 19	+0·17	145	+49)	(*c*)
	1840 III ♂	„ 30	−0·15	172	+68	(*b*)
38	1847 VI ♂	Oct. 4	−0·26	54	+52	(B)
39	1723 ☊	„ 9	+0·06	112	− 7	(*a*) B (*c*)
40	1825 II ♂	„ 7	−0·11	134	+77	(B)
41	1580 ☊	„ 16	+0·18	61	−17	*a*′ C (*c*) (?) (?)
42	1850 II ♂	„ 19	−0·12	2	+54	A (C,) (*c*)
43	1779 ♂	„ „	−0·02	39	−30	(A) (*c*)
44	1842 II ♂	„ 21	−0·14	81	+57	C, (*b*′) (C)
	1848 I ♂	„ 25	−0·23	78	+60	(B) (B′)
45	1739 ♂	„ 22	+0·08	157	+39	A ″ (*c*)
46	1757 (☋) ♂	„ 29 (−21)	−0·33 (+0·08)	30 (−10)	+26 (−7)	(*a*) *a*, (*c*)
47	1695 ♂	Nov. 1	−0·12	318	+53	(*a*)
48	837 I ♂	„ 4	+0·34	104	+27	A ; (*c c′ c″*) B, ?
49	(1582 (?) ♂	„ 9	0·0	89	+36)	(? *Geminids*)
	1821 ☊	„ 11	+0·03	86	+19	(*a*) C *c* (*c*)
50	1813 I ☊	„ 24	−0·30	147	0	(*c*,)
51	1798 II ♂	Dec. 2	−0·14	162	+34	*b′ c c″* C ;
52	1812 ♂	„ 6	−0·20	200	+68	(C) *c*, ? ″
53	1790 II = 1858 I ♂	„ 20	+0·07	221	+77	(?,)
54	1743 I (☊) ☊	Dec. 21 (−16)	−0·14 (−0·02)	7 (+14)	− 2 (+6)	(*b*)
55	1680 ♂	„ 26	−0·05	132	+21	*b″* (*b*) *b″ c″*
1*a*	1759 III ☊	Jan. 19	(−0·05)	210	−15	(B) ?
	(Perih. ☊)	(+20, +40)	(−0·07 −0·08)	(+21 +43)	(−6 −10)	
37*a*	1763 ☊	Sept. 20	−0·03	44	−24	(*c*) (?)
50*a*	1702 II ☋	Nov. 29	(−0·07)	56	+18	(B′) (A″;) A ; (? *Taurids*)

Papers read before the Society from February 1875 to February 1876.

1875.

March 12. On the Method to be used in reducing the Observations of the Transit of *Venus*, 1874, December 8. The Astronomer Royal.

Observations of the Total Solar Eclipse of 1874, April 16, in South Africa. Mr. Stone.

Observations of the Solar Eclipse of 1874, April 16, at the Royal Observatory, Cape of Good Hope. Mr. Stone.

New Elements of μ^2 *Boötis*. Dr. Doberck.

Report on the Progress made in the Calculations for a new Method of treating the Lunar Theory. The Astronomer Royal.

Description of the Transit of *Venus*, as observed at Mooltan, Punjab, India. Capt. Bigg-Wither.

Observations of the Transit of *Venus* at the Royal Observatory, Cape of Good Hope. Mr. Stone.

Report on the Observations of the Transit of *Venus* at Melbourne and subsidiary stations. Mr. R. L. J. Ellery.

Report on the Observations of the Transit of *Venus* at Sydney and subsidiary stations. Mr. H. C. Russell.

Observations of the Transit of *Venus* at Windsor, New South Wales. Mr. J. Tebbutt.

On the Application of Corrections for Change of Temperature to the Rates of Chronometers at Sea. Mr. J. Hartnup.

Catalogue of Micrometrical Measurements of Double Stars made at the Temple Observatory, Rugby, by Messrs. Wilson and Seabroke.

Observations of the Satellites of the planet *Uranus*, made at Birr Castle during the years 1872, 1873, and 1874. Lord Rosse.

Measures of 485 Double Stars made at Mr. Crossley's Observatory, Bermerside, Halifax. Mr. J. Gledhill.

Additional Observations of Comet III, 1874 (Coggia). Mr. J. Tebbutt.

Venus on the Sun's limb, at the Transit of 1874. Mr. Stone.

Discovery of Minor Planet (143). M. Palisa.
Ephemeris for Physical Observations of *Mars* at the Opposition of 1875. Mr. Marth.
Note on the Transit of *Venus*. Mr. J. E. Gore.
On the Colour of *Uranus*. Capt. Noble.
Photography in the Transit of *Venus*. Capt. Abney.

April 9. On the Relative Rectilinear Motion of the Components of 61 *Cygni*. Mr. J. M. Wilson.
On an Investigation by Bessel on the Refraction through an Atmosphere. Mr. E. Neison.
Note on the Supposed Trapezoid Shape of the Sun's Corona. Mr. S. M. Drach.
Observations of the Transit of *Venus* at Vizagapatam. Mr. A. V. Nursinga Row.
Account of Longitude Operations on the way from Mauritius homewards. Lord Lindsay.
Observations of the Satellites of *Saturn* made in 1874 at the Washington Observatory. Professors Newcomb and Holden.
Note on the Star 61 *Geminorum*. Rev. T. W. Webb.
Photography in the Transit of *Venus*. Mr. R. A. Proctor.
On a Theorem in Elliptic Motion. Prof. Cayley.
Measurements of the Distance between *Venus* and the Sun during the Transit of *Venus* with Airy's Double-image Micrometer. Mr. R. L. J. Ellery.
On an Instrument for giving a Mono-chromatic Image of a Circular Slit. Mr. Ranyard.

May 14. On the Period of the Double Star η *Coronæ Borealis*. Mr. J. M. Wilson.
Note on the Proper Motion of the Star in *Cetus* marked 793 in the British Association Catalogue. Prof. C. P. Smyth.
Right Ascensions of 103 Fundamental Stars. Prof. Gyldén (abstract by Mr. Wackerbarth).
Observations and Orbit of the Double Star Σ 1728=42 *Comæ Berenices*. M. O. Struve.
On the Proper Motion of B.A.C. 793. Mr. Dunkin.
On the Dimensions of *Venus* as determined during the recent Transit. Colonel Tennant.
On the Star 61 *Geminorum*. Mr. G. Knott.
Note on the Determination of the Scale in Photographs of the Transit of *Venus*. Mr. W. H. M. Christie.
Memoranda of Observations on the Transit of *Venus*, December 9, 1874. Mr. H. L. Spindler.

June 11. Note on the Suspected Variability of B.A.C. 740, 4166, and 4193. Colonel Tennant.
Note on the Erection of Mr. De La Rue's Telescope at the New Observatory of the University of Oxford. Mr. De La Rue.

Comparison of the Right Ascension and Declination of Standard Stars observed at Oxford in 1872 with the Tabular Right Ascension and Declination in the *Berliner Jahrbuch*. Dr. Wolfers.

On the Application of the Method of Limiting Apertures to the Photometry of Naked-Eye Stars. Mr. Knobel.

On Photography in the Transit of *Venus*. Mr. R. A. Proctor.

Occultations of Stars by the Moon and Phenomena of *Jupiter's* Satellites observed at the Radcliffe Observatory. Rev. R. Main.

Note on the Discovery of Three Minor Planets (144), (145), and (146). Mr. Dunkin.

Sur les prochaines Oppositions de *Mars* pour la Détermination de la Parallaxe solaire. M. Liais.

Note on Two Old Instruments presented to the Society. Mr. Lecky.

On a Diaphanometer. Capt. Abney.

Additional Note on the Proper Motion of B.A.C. 793 (Piazzi II, 123). Mr. Dunkin.

Observations of Coggia's Comet (III, 1874). Mr. J. Tebbutt.

Note on the Positions of the Equinoxes. Prof. S. Newcomb.

Remarks on Drawings of *Jupiter* made by Miss Hirst at Auckland, New Zealand. Mr. S. J. Lambert.

Phenomena of *Jupiter's* Satellites observed at Mr. E. Crossley's Observatory, Bermerside, Halifax. Messrs. E. Crossley and J. Gledhill.

Occultation of *Mars* observed at Windsor, New South Wales. Mr. J. Tebbutt.

Note on a Successful Attempt to Support a Mercury Trough by a Compact and Easily Removable Arrangement. Col. Tennant.

Note on Mr. Pritchard's Ephemeris of Circumpolar Stars. Col. Tennant.

Drawings of *Mars* and *Jupiter* made with the 26-in. Equatoreal of the U.S. Naval Observatory. Prof. Holden.

Catalogue of Points on the Moon's Surface whose Position has been recently determined by Micrometrical Measures. Mr. E. Neison.

On the Error of the Tabular Place of *Venus* during the Transit of December 8, 1874. Col. Tennant.

Note on the Discovery and Observations of Six Minor Planets (149) to (154). Mr. Dunkin.

Observations of the Zodiacal Light at Cadiz. Señor Arcimis.

Partial Eclipse of the Sun, 1875, September 28–9, observed at Forest Lodge, Maresfield. Capt. Noble.

Occultations of ζ *Arietis* and χ *Aquarii* by the Moon observed at Forest Lodge, Maresfield. Capt. Noble.

On the Aspect of the Zodiacal Light opposite the Sun. Mr. T. W. Backhouse.

On the Preparations which are being made on the Continent for Promoting Physico-Astronomical Observations. Mr. De La Rue.

Observations of the Solar Eclipse of 1875, September 28–9, made at the Royal Observatory, Greenwich. The Astronomer Royal.

Chart of the Apparent Path of *Mars*, 1877. The Astronomer Royal.

Notes to accompany Drawings of Coggia's Comet by Mrs. Newall. Mr. R. S. Newall.

Spectroscopic Observations made at the Royal Observatory, Greenwich. The Astronomer Royal.

Note on an Old Picture of the Sun. Signor Capello.

On the State of the Reductions of the Observations of the Transit of *Venus*. Lord Lindsay and Mr. Gill.

On the University Observatory at Oxford. Prof. Pritchard.

Dec. 10. Note on the Southern Nebulæ 30 (Bode) *Doradûs* and the Nebula about η *Argûs*. Mr. C. E. Burton.

Note on a New Variable Star in *Capricornus*. Mr. J. E. Gore.

On the Posthumous Papers of the late Prof. Rigaud. Major-Gen. Rigaud.

Results of some Experiments with Huygens's Parabolic Pendulum for obtaining Uniform Rotation. Mr. R. L. J. Ellery.

On the Double Star 61 *Geminorum*. Rev. S. J. Johnson.

Transit of *Venus*: Manila Photographs. Rev. S. J. Perry.

The November Meteors. Rev. S. J. Perry.

On a Drawing of the Ring Nebula in *Lyra*. Prof. E. S. Holden.

On some Old Pictures of *Saturn*. Mr. C. L. Prince.

On a New Form of Observing Chair. Mr. W. Erck.

Observations on Col. Tennant's Experiments on the Proper Form of a Mercurial Trough for Collimation by Reflection of Wires. Prof. Pritchard.

On the Oxford Ephemeris of Twelve Close Circumpolar Stars for 1875. Prof. Pritchard.

Ephemeris for Determining the Positions of the Satellites of *Uranus*, 1876. Mr. Marth.

Observations of Coggia's Comet. Mr. G. H. With.

Note on the Duplicate Structure of Coggia's Comet. Mr. Ranyard.

1876
Jan. 14. Eclipses of *Jupiter's* Satellites, 1875. Mr. J. Tebbutt.
Greenwich Times of Egypt Transit of *Venus* Observations. With Remarks as to Different Phases and Discordances in the Times. Capt. C. Orde Browne.
Report by the Astronomer Royal on the Present State of Calculations in his New Lunar Theory. Sir G. B. Airy.
Observations of the Solar Eclipse of 1875, Sept. 29, made at the University Observatory, Strasburg. Prof. Winnecke.
Note on the Double Stars Σ 1156 and Σ 1163. Mr. S. W. Burnham.
Note on Two Parallel Observations. Mr. J. Brett.
On Astronomical Nomenclature. Mr. J. I. Plummer.
Note on the Variable Star S *Orionis*. Rev. T. W. Webb.
On a New Form of Solar Eyepiece. Mr. W. H. M. Christie.
Occultations of Stars by the Moon and Phenomena of *Jupiter's* Satellites observed at the Royal Observatory, Greenwich, 1875. The Astronomer Royal.
On the Chronology of Star Catalogues. Mr. Knobel.
Note on the Biblical Synodic Lunar Cycles. Mr. S. M. Drach.
On the Proper Motion of Bradley's Stars. Mr. J. I. Plummer.
Ephemeris for Physical Observations of *Jupiter*. Mr. Marth.

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ADDRESS

Delivered by the President, Professor Adams, on Presenting the Gold Medal of the Society to M. Le Verrier.

It has been already announced to you that the Council have awarded the Society's medal to M. Le Verrier for his theories of the four great planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and for his tables of *Jupiter* and *Saturn* founded thereupon. It now becomes my pleasing duty to explain to you the grounds of this award.

I need not, on the present occasion, enter into any detail respecting the previous achievements of our distinguished Associate, and the numerous and valuable researches with which he has enriched our science. These will be fresh in your recollection, and they have already been eloquently described to you from this chair.

It is not many years since our medal was awarded to M. Le Verrier for his theories and tables of the four planets nearest the Sun, viz. *Mercury*, *Venus*, the *Earth*, and *Mars*. Long before this he had been occupied with the larger planets, but before proceeding further with their theories he found it necessary to establish on solid foundations the theory of the motion of the Earth, on which all the rest depend, and this again naturally led him to investigate the theories of the three nearer planets which, with the Earth, constitute the inferior portion of the planetary system.

By the comparison of these theories with observations, M. Le Verrier was led to two interesting results. He found that in order to bring the theories of *Mercury* and *Mars* into accordance with observation, it was necessary and sufficient to increase the secular motion of the perihelion of *Mercury*, and also the secular motion of the perihelion of *Mars*.

Hence M. Le Verrier inferred that there existed, on the one hand, in the neighbourhood of *Mercury*, and on the other, in the neighbourhood of *Mars*, sensible quantities of matter, the action of which had not been taken into account.

This conclusion has been verified with respect to *Mars*. The matter which had not been considered turns out to belong to the Earth itself, the mass of which had been taken too small, having been derived from too small a value of the solar parallax. A similar increase of the mass of the Earth is indicated by the theory of *Venus*, and a corresponding increase of the solar parallax is likewise derived from the lunar equation in the motion of the Sun.

With respect to *Mercury*, a similar verification has not yet

taken place, but the theory of the planet has been established with so much care, and the transits of the planet across the Sun furnish such accurate observations, as to leave no doubt of the reality of the phenomenon in question; and the only way of accounting for it appears to be to suppose, with M. Le Verrier, the existence of several minute planets, or of a certain quantity of diffused matter circulating about the Sun within the orbit of *Mercury*.

The results which M. Le Verrier had thus obtained from his researches on the motions of the interior planets added to the interest with which he now entered upon similar researches on the system of the four great planets which are the most distant from the Sun. Such researches might furnish information respecting matter hitherto unknown existing in the neighbourhood of these planets. Possibly they might afford indications of the existence of a planet beyond *Neptune*, and at any rate they would provide materials which would facilitate future discoveries.

As I shall have occasion to explain later on, the theories of the mutual disturbances of the larger planets are far longer and more complicated than those of the smaller, so that all that M. Le Verrier had yet done might be almost regarded as merely a prelude to what still remained to be done. Increased difficulties, however, far from deterring, seemed rather to stimulate him to greater exertions.

On the 20th of May, 1872, M. Le Verrier presented to the Academy an elaborate memoir, containing the first part of his researches on the theories of the four superior planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*. This memoir contains an investigation of the disturbances which each of these planets suffers from the action of the remaining three. Throughout this investigation the development of the disturbing function, as well as that of the inequalities of the elements is given in an algebraical form, in which everything which varies with the time is represented by a general symbol, so that the expressions obtained hold good for any time whatever. Thus the excentricities and inclinations, the longitudes of the perihelia and of the nodes are all left in the condition of variables. The mean parts of the major axes, which suffer no secular variations, are alone treated as given numbers.

At the end of the *résumé* of the contents of this memoir, given in the *Comptes Rendus*, M. Le Verrier lays down the following almost appalling programme of the work still remaining to be done.

It would be necessary, he says

1. To calculate the formulæ, and to reduce them into provisional tables.
2. To collect all the exact observations of the four planets, and to discuss them afresh, in order to refer their positions to one and the same system of co-ordinates.
3. By means of the provisional tables, to calculate the

apparent positions of the planets for the epochs of the observations.

4. To compare the observed with the calculated positions, to deduce the corrections of the elliptic elements of the four planets, and to examine whether the agreement is then perfect.
5. In the contrary case, to find the causes of the discrepancy between theory and observation.

Extensive as is this programme, it has already been completely carried out as regards the planets *Jupiter* and *Saturn*, and partly so as regards *Uranus* and *Neptune*.

Having received from the Academy the most effectual encouragement to pursue his researches, M. Le Verrier lost no time in bringing them gradually to completion, so that they might become available for practical use.

Accordingly, on the 26th of August, 1872, he presented to the Academy a memoir containing a complete determination of the mutual disturbances of *Jupiter* and *Saturn*, and thus serving as a base for the theories of both these planets, which are closely connected with each other.

Again, on the 11th of November, 1872, he presented his determination of the secular variations of the elements of the orbits of the four planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*. These variations are mutually dependent on each other, and must be treated simultaneously. Their determination consequently involves the solution of sixteen differential equations, which are very complicated in form, and can only be integrated by repeated approximations.

This part of the work forms a necessary preliminary to the treatment of the theory of any one of these planets in particular.

On March 17, 1873, M. Le Verrier presented to the Academy the complete theory of *Jupiter*; and on July 14 in the same year he followed it up by the complete theory of *Saturn*.

On January 12, 1874, he presented his tables of *Jupiter*, founded on the theory which has just been mentioned, as compared with observations made at Greenwich from 1750 to 1830 and from 1836 to 1869, and with observations made at Paris from 1837 to 1867.

Again on November 9, 1874, he presented to the Academy a complete theory of *Uranus*. Already in 1846, in his researches which led to the discovery of *Neptune*, M. Le Verrier had given a very full investigation of the perturbations of *Uranus* by the action of *Jupiter* and *Saturn*. In the memoir just mentioned he gives a fresh investigation, including a full treatment of the perturbations of *Uranus* by the action of *Neptune*.

On December 14, 1874, he presented a new theory of the planet *Neptune*, thus completing the theoretical part of the immense labours which he had undertaken with respect to the planetary system.

Finally, on August 23, 1875, he presented to the Academy the comparison of the theory of *Saturn* with observations.

Such is a bare enumeration of the various labours for which our science is already indebted to our illustrious Associate.

That any one man should have had the power and perseverance required thus to traverse the entire solar system with a firm step, and to determine with the utmost accuracy the mutual disturbances of all the primary planets which appear to have any sensible influence on each other's motions, might well have appeared incredible if we had not seen it actually accomplished.

I will now proceed to give a brief outline of the investigations relating to the motions of the four larger planets, with which we are now more particularly concerned. The most important parts of these investigations are printed in full detail in the volumes of *Memoirs* which form part of the *Annals of the Observatory of Paris.*

As in his former researches, M. Le Verrier here also exclusively employs the method of variation of elements, and the investigations are based on the development of the disturbing function given by him, in the first volume of the *Annals of the Paris Observatory*, with greater accuracy and to a far greater extent than had ever been done before.

The 18th Chapter of M. Le Verrier's researches, which forms nearly the whole of the 10th Volume of the *Memoirs*, is devoted to the determination of the mutual action of *Jupiter* and *Saturn*, which forms the foundation of the theories of these two planets.

These theories are extremely complicated, and I shall endeavour briefly to point out, and to explain as far as I can without the introduction of algebraical symbols, the nature of the peculiar difficulties which M. Le Verrier has had to encounter in their treatment, and which he has so successfully overcome. These difficulties either do not present themselves at all, or do so in a very minor degree in the theories of the smaller planets.

First, then, the masses of *Jupiter* and *Saturn* are far larger than those of the interior planets, the mass of *Jupiter* being more than 300 times and that of *Saturn* being nearly 100 times greater than the mass of the Earth. For this reason it is necessary to develop the infinite series in which the perturbations are expressed to a much greater extent when we are dealing with *Jupiter* and *Saturn*, than when we are concerned with the mutual disturbances of the interior planets. Also *Jupiter* and *Saturn* are so far removed from these latter planets that the disturbances which they produce in the motion of these planets are extremely small, in spite of the large masses of the disturbing bodies.

But the great magnitude of the disturbing masses is far from being the only reason why the theory of the mutual disturbances of *Jupiter* and *Saturn* is so complicated.

Another cause which aggravates the effect of the former is the near approach to commensurability in the mean motions.

1. Those which involve the mean longitudes of one or both of the planets concerned, as well as the elements of their orbits.
2. Those which involve the elements only.

The first are called periodic terms, since they pass from positive to negative, and *vice versâ*, in periods comparable with those of the planets themselves.

The second are called secular terms, and vary very slowly, since the elements on which they depend do so.

Each of the terms in the expression of the rate of variation of any element will involve the mass of one of the disturbing bodies as a factor.

Hence, if all these masses be very small, all the periodic inequalities of the elements will be likewise very small, and we shall obtain a value of the rate of variation which is very near the truth if we substitute for the complete value of any element its value when cleared of periodic inequalities.

Then the periodic inequalities in the element under consideration may be found by direct integration, supposing the elements to be constant in the terms to be integrated, and the mean longitudes only to vary.

Also the secular variation of the element considered, that is the rate of variation of the element when cleared of periodic inequalities, will be given by the secular terms taken alone.

If the disturbing masses, however, are not very small, this process is not sufficiently accurate, and the periodic inequalities thus found can only be regarded as a first approximation to the true values.

In order to find more correct values, we must substitute for the elements in the second member of the equation their secular parts augmented by the approximate periodic inequalities before found.

Now, if in any periodic term we increase any element by a periodic inequality depending on a different argument, that is involving different multiples of the mean longitudes, the result will evidently be to introduce new periodic terms which will involve the square of one of the masses or the product of two of them as a factor.

Similarly, if in any periodic term any element be increased by a periodic inequality depending on the same argument, the result will also introduce new terms of the second order which do not involve the mean longitudes, and which therefore constitute new secular terms.

These will be particularly important if the inequality in question be one of long period.

Also in the secular terms the result of increasing any element by a periodic inequality will be to introduce a new periodic term depending on the same argument.

Lastly, it should be remarked that in finding the periodic inequalities of any element by integration of the corresponding

substituting from the beginning the numerical values of the elements at a given epoch, the calculation is rendered much shorter and admits much more readily of verification; but the result thus obtained only holds good for the given epoch, and is thus entirely wanting in generality.

In the determination of the long inequalities of *Jupiter* and *Saturn*, the approximation is carried to terms which are of the seventh degree with respect to the excentricities and the mutual inclination of the orbits.

In the next place the terms of the first order in the secular variations of the elements of the orbits are determined.

After this the periodic inequalities of the second order with respect to the masses are considered. These are determined in the same form as the terms of the first order, in order that their expressions may hold good for any epoch whatever. The formulæ relating to these terms are necessarily very complicated. The coefficient belonging to a given argument depends, in general, on a great number of terms which are classed methodically.

Next are determined the terms of the second order in the secular variations of the elements of the orbits.

Afterwards, M. Le Verrier takes into account the influence of the secular inequalities on the values of the integrals on which the periodic inequalities depend.

The last part of this chapter is devoted to the completion of the differential expressions of the secular inequalities by the determination of certain secular terms in the rates of variation of the excentricities and the longitudes of the perihelia, which are of the third and fourth orders with respect to the masses.

The 19th Chapter of M. Le Verrier's researches, which forms the first part of the 11th Volume of the *Annals of the Paris Observatory*, contains the determination of the secular variations of the elements of the orbits of the four planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*.

In the first place are collected the differential formulæ which are established in the previous chapter, and which give the rates of secular change of the various elements at any epoch in terms of the elements themselves, which by the previous operations have been cleared of all periodic inequalities.

The terms of different orders which enter into these formulæ are carefully distinguished.

If we were to confine our attention to the terms of the first degree with respect to the excentricities and inclinations of the orbits, and of the first order with respect to the masses, the differential equations which determine the secular variations would become linear, and their general integrals might be found, so as to give the values of the several elements for an indefinite period.

In the present case, however, the terms of higher orders are far too important to be neglected, and when these are taken into

account the equations become so complicated as to render it hopeless to attempt to determine their general integrals.

Fortunately, however, these are not needed for the actual requirements of Astronomy, and for any definite period the simultaneous integrals may be determined with any degree of accuracy that may be desired by the method of quadratures.

In this way M. Le Verrier has determined the values of the elements for a period of 2000 years, starting from 1850, at successive intervals of 500 years. The first steps in this integration were attended with some difficulties, because the determination of the numerical values of the rates of change of the several elements at the various epochs depends on the elements themselves which are to be determined. Hence several approximations were necessary in order to obtain the requisite precision.

After this work of M. Le Verrier, however, the extension of the investigation to other epochs, past or future, is no longer attended with the same difficulties. In fact, from his results we may at once find, by the method of differences, very approximate values of the elements at an epoch 500 years earlier or later than those which he has considered. His general formulæ will then give the rates of change of the several elements at the epoch in question, and having these we can determine by a direct calculation the small corrections which should be applied to the approximate values of the elements first found.

This process may evidently be repeated as often as we choose.

It is important to remark that in the formulæ which give the rates of change of each of the elements at the five principal epochs considered, as well as in those which give the total variations of the elements at the same epochs, the masses of the several planets appear in an indeterminate form, so that it may be at once seen what part of the variation of any element is due to the action of each of the planets, and what changes would be produced in the value of any element at any epoch by any changes in the assumed values of the masses.

Consequently, when the astronomer of the future, say of 2000 years hence, has determined the values of the elements of the planetary orbits corresponding to that epoch, it will be easy for him, by comparing those values with the general expressions given by M. Le Verrier, to determine with the greatest precision the actual values of the masses, provided that all the disturbing bodies are known; and should there be any unknown disturbing causes, their existence would be indicated by the inconsistency of the values of the masses which would be found from the different equations of condition.

By means of the work which has just been described everything has been prepared which is required for the treatment of the theories of the several planets.

The remainder of the 11th Volume of the *Annals* is accordingly occupied by the complete theories of *Jupiter* and *Saturn*, the

former theory being given in Chapter 20 and the latter in Chapter 21 of M. Le Verrier's researches.

The coefficients of the periodic inequalities of the mean longitudes and of the elements of the orbits are not only exhibited in a general form, but are also calculated numerically for the five principal epochs considered in Chapter 19 of these researches, viz. for 1850, 2350, 2850, 3350, and 3850.

The long inequalities of the second order with respect to the masses, depending on twice the mean motion of *Jupiter* plus three times the mean motion of *Uranus* minus six times the mean motion of *Saturn*, are also determined in a similar form.

Chapter 22 of M. Le Verrier's researches, forming the first part of the 12th Volume of the *Annals*, contains the comparison of the theory of *Jupiter* with the observations, the deduction of the definitive corrections of the elements therefrom, and finally the resulting tables of the motion of *Jupiter*.

The observations employed are the Greenwich observations from 1750 to 1830 and from 1836 to 1869, together with the Paris observations from 1837 to 1867.

To the results given in the Astronomer Royal's "Reduction of the Greenwich Observations of Planets from 1750 to 1830" M. Le Verrier has applied the corrections which he has found to be required by his own reduction of Bradley's observations of stars and his redetermination of the Right Ascensions of the fundamental stars, published in the 2nd Volume of the *Annals* (Chapter 10).

The equations of condition in longitude, for finding the corrections of the elements and of the assumed mass of *Saturn*, are divided into two series corresponding to the observations made from 1750 to 1830, and into two other series corresponding to the observations made from 1836 to 1869.

Moreover, in each of these series the equations are subdivided into eight groups, corresponding to the distances of the planet from its perihelion, 0° to 45°, 45° to 90°, and so on.

From these are formed four final equations, the solution of which gives the corrections of the epoch, of the mean motion, of the excentricity, and of the longitude of the perihelion, in terms of the correction required by the mass of *Saturn*, which is left in an indeterminate form.

The substitution of these expressions in the thirty-two normal equations corresponding to the several groups above mentioned gives the residual differences between theory and observation in terms of the correction of the mass of *Saturn*.

No conclusion can be drawn from the ancient observations; but from the modern observations M. Le Verrier finds that the mass of *Saturn* assumed—which is that of Bouvard—should be diminished by about its $\frac{1}{100}$th part. This correction is very small, but M. Le Verrier regards it as well established.

On the other hand, Bessel's value of the mass of *Saturn*,

tables will greatly surpass that of the observations which we have to compare with them.

M. Le Verrier's Tables of *Jupiter* are now employed in the computations of the *Nautical Almanac*, beginning with the year 1878.

The 13th Volume of the *Annals* is devoted to the theories of *Uranus* and *Neptune*. These theories are not unattended with difficulties.

In the first place, these planets are disturbed by the actions of the two great masses, *Jupiter* and *Saturn*, interior to their orbits, and these actions are modified by the great inequalities of *Jupiter* and *Saturn* depending on five times the mean motion of *Saturn* minus twice the mean motion of *Jupiter*.

In the next place, twice the mean motion of *Neptune* differs very little from the mean motion of *Uranus*, and thus arise inequalities of long period in the elements of their orbits which are large enough to produce very sensible terms of the second order.

Lastly, the mean elliptic elements of the two planets are not yet sufficiently well known.

In a preliminary chapter, the 24th, M. Le Verrier investigates formulæ which are specially applicable to the case of a planet disturbed by another which is considerably nearer to the Sun.

In this case it is easily seen that, by the direct action of the disturbing planet on the Sun, perturbations of large amount may be produced in the *elements* of the orbit of the disturbed planet, while the corresponding perturbations of the co-ordinates of the planet are comparatively small. Hence arises the advantage of considering this case apart.

We have seen how closely the theories of *Jupiter* and *Saturn* are related to each other. In a similar manner the theories of *Uranus* and *Neptune* are also closely related in consequence of the great perturbations introduced into the elements of their orbits by the near approach to commensurability in their mean motions.

Hence, before entering upon the separate theories, M. Le Verrier devotes Chapter 25 of his researches to the determination of the mutual actions of *Uranus* and *Neptune*, and this forms the base of the theories of both planets.

The method employed is similar to that adopted in the case of *Jupiter* and *Saturn*, and the results are exhibited in the same general form.

It is important to remark that the elements of *Uranus* and *Neptune* as determined from observations severally differ from their mean elliptic values by the amount of their perturbations of long period corresponding to the mean epoch of the observations.

The apparent elements of *Uranus* and *Neptune* for the epoch 1850 have been carefully determined by Professor Newcomb in his excellent work on the theory of those planets which obtained the Society's Medal in 1874.

By the application of his own general formulæ, M. Le Verrier deduces from these elements the values of the mean elliptic elements corresponding to the same epoch.

It may be remarked that the mean elements thus determined will depend on the assumed masses of the two planets, and will therefore require small corrections when more accurate values of the masses have been obtained.

When the secular variations of *Uranus* and *Neptune* given in Chapter 19 were found, the elements were less accurately known, and M. Le Verrier has therefore recalculated the values of the excentricities and longitudes of the perihelia of the two planets for the same five epochs as before, starting from the mean elliptic values of the elements above referred to.

Chapter 26 contains the completion of the theory of *Uranus*. The last chapter, which contains the completion of the theory of *Neptune*, is not yet printed.

The 23rd chapter also, which contains the comparison of the theory of *Saturn* with observations, together with the tables of the planet, and which will form the latter part of the 12th Volume of the *Annals*, is not yet printed. The results of this comparison of the theory with observations have, however, been fully published in the *Comptes Rendus*, and I understand that the tables will be used for computing the place of *Saturn* in the forthcoming volume of the *Nautical Almanac*.

Although the comparison of the theory of *Saturn* with observations shows in general a satisfactory accordance, there occur some discrepancies in individual years which are larger than might be desired.

During the thirty-two years over which the modern observations extend, viz. from 1837 to 1869, the discrepancy between theory and observation, however, remains constantly less than $2''{\cdot}5$ of arc, excepting in two instances, viz. in the years 1839 and 1844, when the differences amount to $4''{\cdot}5$ of arc.

In the ancient observations only, made in the time of Maskelyne, rather larger differences occur, amounting in two instances to nearly $9''$ of arc.

In order to test whether these discrepancies could be due to any imperfections in the theory, M. Le Verrier has not shrunk from the immense labour of forming a second theory of the planet independent of the former, employing methods of interpolation instead of the analytical developments.

I learn directly from M. Le Verrier that this second investigation entirely confirms the accuracy of the first as regards the periodic inequalities, but that the secular variations of the excentricity and longitude of the perihelion are slightly changed.

The effect of these changes is to bring the theory into very satisfactory accordance with the observations of Bradley, but the discrepancies above mentioned in the time of Maskelyne and in the modern observations still remain unaffected.

The character of the discrepancies shown by the modern ob-

servations makes it very improbable that they can be due to any errors in the theory.

In fact, the error appears to change almost suddenly from a positive one of 4″·4 in 1839 to a negative one of 5″·0 in 1844, a variation of nearly 9″·5 in five years. Now no terms or group of terms due to the action of the planets could thus suddenly disturb the motion in five years, at a given epoch, and then leave the motion unaffected during the following twenty-five years.

M. Le Verrier is therefore inclined to think that the discrepancies arise from errors in the observations, notwithstanding that the Greenwich and Paris observations are mutually confirmatory of each other.

He suggests that it is possible that the varying aspects presented at different times by the ring may affect the accuracy of the observations of the planet, and may cause changes in the personal equations of the observers, which, from being rather large in the case of the ancient observations, have gone on diminishing as the system of observation has become more perfect.

One unlooked-for result follows from M. Le Verrier's comparison of his theory of *Saturn* with the observations. Considering that the influence of *Jupiter* on the longitude of *Saturn* may amount to 3800″, it might have been expected that from observations of the planet extending over 120 years the mass of *Jupiter* could have been determined with great precision. M. Le Verrier has found, however, that this is not the case.

The equations of condition furnished by the comparison of the heliocentric longitudes of *Saturn* as deduced from theory and observation contain five unknown quantities, viz. the corrections of the assumed values of four elements and the correction of the assumed mass of *Jupiter*.

On solving the equations with respect to the first four unknown quantities, the corrections to be applied to the elements are found to be greatly influenced by the indeterminate correction of the mass of *Jupiter*, and after they have been substituted in the equations of condition, the coefficients of the correction of the mass of *Jupiter* in great part destroy each other, nowhere amounting in the resulting equations to one-tenth part of their values in the primitive equations. Hence these equations are insufficient to determine the mass of *Jupiter* with any precision.

Consequently, in the formation of the Tables of *Saturn*, M. Le Verrier has employed the value of the mass of *Jupiter* determined by the Astronomer Royal from his observations of the 4th satellite.

The result which has just been noticed will appear to be less paradoxical if we consider that by far the larger part of the disturbances which *Jupiter* produces in the motion of *Saturn* is represented by the inequalities of long period which affect the mean longitude and the elements of the orbit. Now in the course of 120 years these inequalities have run through only a

small part of their whole period, and therefore, during this interval, the greater part of their effects may be represented by applying changes to the several mean elements equal to the mean value of the corresponding long inequalities during the interval. It is only from the residual disturbances, which are comparatively small in amount, that any data can be obtained for the correction of the mass of *Jupiter*.

In the course of a few centuries, when these long inequalities, as well as the secular variations of the elements of *Saturn*, shall have had time to develop themselves, it will be possible to determine the mass of *Jupiter* from them with all desirable precision.

I trust that the review which I have just given, however hasty and imperfect, of the work of our distinguished Associate has been sufficient to convince you that your Council have done well in according him your Medal.

In conclusion, I may be allowed to express the great satisfaction I have felt in becoming the mouthpiece of the Council on this occasion, and in thus joining in doing honour to the eminent Astronomer whose untiring labours have added so greatly to our knowledge of the motions of the principal members of our Solar system.

The President then, delivering the Medal to the Foreign Secretary, addressed him in the following terms:

Dr. Huggins—In transmitting this Medal to M. Le Verrier, you will express to him the interest with which we have followed his unwearied researches, and the admiration which we feel for the skill and perseverance by which he has succeeded in binding all the principal planets of our system, from *Mercury* to *Neptune*, in the chains of his Analysis. You can tell him how sorry we are not to see him among us on the present occasion, and how glad we shall be to welcome him if he is able to visit us later in the session. We hope that he will then have finished the printing of his "Tables of *Saturn*" and his "Theory of *Neptune*," and thus be able to rest awhile and re-establish his health—shaken, we fear, by his too arduous labours—until he goes forth again, with fresh vigour, to win new triumphs in the fields of Physical Astronomy.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected:—

President.

William Huggins, Esq., D.C.L., LL.D., F.R.S.

Vice-Presidents.

J. C. Adams, Esq., LL.D., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Sir G. B. Airy, K.C.B., D.C.L., LL.D., F.R.S., Astronomer-Royal.
Warren De La Rue, Esq., D.C.L., F.R.S.
William Lassell, Esq., LL.D., F.R.S.

Treasurer.

Samuel Charles Whitbread, Esq., F.R.S.

Secretaries.

Edwin Dunkin, Esq.
A. Cowper Ranyard, Esq., M.A.

Foreign Secretary.

Lord Lindsay, M.P.

Council.

Captain William De W. Abney, R.E.
John Brett, Esq.
Arthur Cayley, Esq., LL.D., F.R.S., Sadlerian Professor of Geometry, Cambridge.
W. H. M. Christie, Esq., M.A.
J. W. Lee Glaisher, Esq., M.A., F.R.S.
E. B. Knobel, Esq.
George Knott, Esq.
Captain William Noble.
Rev. S. J. Perry, F.R.S.
Rev. Charles Pritchard, M.A., F.R.S., Savilian Professor of Astronomy, Oxford.
Earl of Rosse, B.A., D.C.L., F.R.S.
Captain G. L. Tupman, R.M.A.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVI. *March* 10, 1876. No. 5.

WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

William James Allsup, Esq., 5, Eastcombe Villas, Blackheath; John William Durrad, Esq., 12, Lincoln Street, Leicester; and The Rev. Joseph Ferguson, 108, Lupin Street, Birmingham;

were balloted for and duly elected Fellows of the Society.

Mr. Carrington's Sun-Spot MSS.

Lord Lindsay has recently presented to the Society the drawings of Solar Spots, and manuscript books of observations and reductions of observations, which were made by the late Mr. Carrington, between the years 1853 and 1871. The results derived from a great portion of these observations have already been published in Mr. Carrington's book on Sun-Spots; but the interest attaching to the collection is still great, as it contains the original data from which the most accurate determination of the position of the Sun's axis and the drift of the photosphere in the various heliocentric latitudes have been determined.

These manuscripts were recently sold by public auction, and were bid for on the part of the Society; but they were purchased by a bookseller, from whom Lord Lindsay has since bought them, for the purpose of depositing them in our library, which is already comparatively rich in Sun-Spot manuscripts, as will be seen from the following list:

1 vol. of Drawings, by Charles B. Adams. Aug. 1819—March 1822.
3 vols. of Drawings, by J. W. Pastorff. 1819–1833.
2 vols. of Drawings, by the Rev. T. J. Hussey. 1826–1837.
1 vol. of Drawings, by Mr. Lawson. 1831–1832.
1 vol. of Drawings, by Capt. C. Shea. 1847–1866.
2 vols. of Drawings, by the Rev. T. Chevallier. 1847–1849.
Detached Drawings of the Sun, by Sir J. Herschel. 1846.

Mr. Carrington's collection consists of—

Three folio volumes drawings of Sun-Spots, made on a scale of 12 inches to the Sun's diameter. In all cases the whole of the Sun's disk has been drawn, and the positions of the north point and the Sun's axis have been marked upon the page with great care. The places of the spots and the general outline of the groups and penumbræ were, it is believed, laid down by means of an enlarged image of the Sun, which was thrown upon the drawing paper; and the details were afterwards roughly sketched in without any pretension to great accuracy.

Three large quarto volumes of observations of the Positions of Spots. These observations were made by observing the intervals of time between the transits of the spots and the transits of the preceding and following limbs of the Sun across wires in a fixed telescope.

Seven large quarto volumes, containing the reductions of the above observations.

And a folio volume, filled with drawings of groups of Spots as seen upon successive days, placed one below the other on the page, so as to show at a glance the history of the group, and its drift in heliocentric latitude and longitude. A. C. R.

Note on a Starlit Transit Eyepiece.

By Dr. Royston-Pigott, M.A., F.R.S., &c.

In review of the recent weather, so hostile to nice observations, it is with some diffidence that I venture to draw the attention of the Society to the little contrivance which I have named the *Starlit Transit Eyepiece*, as its name implies, self-illuminating.

It essentially consists of transparent lines drawn on a film of silver of a fine blue tint, deposited by Martin's process on a disk of glass. This film admits the view of a star, which can be seen passing across the field and flashing brightly at the instant of transit across the vertical parallel transparent lines. The breadth of the lines can be regulated so that more or less of the spurious disk of a star can be shown in transit. For a 60-inch Transit—the size of the instrument I employ—the lines are ruled $\frac{1}{20}$th of an inch apart, which gives 11·4 seconds of time for the transit of an equatoreal star; spaces of $\frac{1}{20 \cdot 1}$ give 12 seconds.

The lines can be ruled with great exactitude within a 10,000th of an inch: 1,000th of an inch corresponds nearly to a quarter of a second, and 10,000th to the fortieth part of a second. In the centre, below the film, is an indicator, visible by star-light, showing the central line; and the film is removed at the sides so as to show the approach of the star to the transparent lines,

three, five, or seven in number, according to the requirements of the observer.

The films also can be deposited of any degree of opacity, according to the power of the instrument, and can be renewed at a small cost, and be readjusted by proper screws with great readiness to a distant meridian mark.

The diffraction effects peculiar to a cylindrical thread are considerably modified by a bright line formed by plane surfaces. The spider line usually employed is nearly cylindrical, and when illuminated by reflection a cylindrical image only is formed, which does not extend over the whole breadth of the line; whilst an unillumined portion, invisible to the eye, obscures part of the star disk after apparent transit.* An interesting appearance is seen when a good-sized star is put out of focus, so as to show a clearly defined enlarged disk.

As the disk transits over the transparent lines a brilliant line starts into view: at first a very short line, gradually and rapidly lengthening, and again shortening to its point of disappearance.

Applied to my 8-foot Equatoreal with 5¼-inch aperture the effect was beautiful, and produced a strong illusion of the bright line or star being stationary and the transparent bars moving. The inconvenience of artificial illumination with this instrument renders a starlit transit particularly desirable.

The silver film appears to answer very much better than any other film I have hitherto tried; for several attempts have been made with various varnishes and ruled lines; but these varnishes are apt to coalesce, and any variation in thickness and quality destroys uniformity of effect.

In solar transits, provided the brilliance of the solar disk has been sufficiently subdued, whether by Barlow's silvered lenses, polarisation, or neutral glasses, or still better by Mr. Christie's solar eyepiece, the flashing of the edge of the solar limb, as it successively passes across the transparent lines, is a phenomenon worthy perhaps of attention; but whether for solar observations this transparent method is in any degree as trustworthy as opaque line† observations is a point on which I can at present offer no opinion.

Messrs. Horne & Thornthwaite, I wish to add, have beautifully carried out the design of the writer, and have placed at the disposal of the Greenwich, Oxford, and Cambridge Observatories, and of those of Lord Lindsay and Dr. Huggins, five of these instruments.

Hartley Court, Reading,
March 6, 1876.

* The behaviour of minute reflecting threads (especially of spun glass) under the microscope gives some pretty illustrations of cylindrical images, such as those here alluded to.

† These lines may perhaps be successfully photographed for Solar Transits.

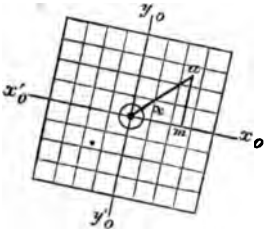
The Stereo-micrometer.

By Professor Chas. V. Zenger.

The stereo-micrometer is a binocular apparatus, to be fitted to any kind of astronomical refracting or reflecting telescope, and is used for measuring at once small angles in the field of view, as, for instance: The position-angles of solar protuberances; of solar spots; of close double stars; of difficult comes; of the satellites of *Jupiter*, *Saturn*, and *Uranus*; finally, of the spectral lines in solar and stellar spectra.

It is also intended, if used with a day eyepiece, to give the position of any terrestrial object, by placing the telescope at two different points, a and b, of a stand-line, measuring thus the coordinates x and y of the same point in two positions, and therefore its parallax, or the distance z by the horizontal parallax, to be deduced from the measurements made on the micrometer, viz., the differences of x and y.

It is constructed on the stereoscopical principle, and consists of two draw tubes exactly similar, with homofocal lenses, both mounted parallel to the axis of the telescope, with an arrangement for different distances of eyes. Looking through the double eyepieces, one being placed before the image of the star in the focus of the telescope, the other having been placed before an ocular micrometer divided in $\frac{1}{10}^{mm}$ or $\frac{1}{20}^{mm}$, forming a grate of small squares on one side of a thin plate of mica; the image of the micrometer is thus projected on the images of the stars in the telescope, the fifth or inside line ($x_o\, x_o'$) of it being set parallel to the diurnal motion; it is easily to be conceived that if a be a comes of a planet or star placed with its centre at o, $am=y$, $om=x$ will be respectively the differences of declination and right ascension of both, and $\tan \alpha = \frac{y}{x}$ will measure the angle between the centre of the star and its comes, taking the direction of the diurnal motion as zero.



The diameter of the planet, the distance of the satellite, the angle of position, or the differences in Declination and R.A. may may be thus observed at a single glance, marking only the number of the small square where the satellite (a) will be seen, and its position in it.

In my Busch Refractor, 4″ aperture and $1^{m}\cdot5$ focal distance, the image of the Sun holds nearly 15^{mm} in diameter: 15^{mm} therefore being equivalent to 300 divisions of the micrometer divided in $\frac{1}{20}^{mm}$, and magnified 25 times by a Ramsden eyepiece, one division being $\frac{1920''}{300} = 6''\cdot4$, it is easy to discern by the eye $\frac{1}{10}$ to $\frac{1}{20}$ of a division in both directions, or nearly $0''\cdot6$ to $0''\cdot3$. There

could easily be placed in the micrometric eyepiece a pair of movable wires to measure accurately in both directions the position of a in the small square.

The fifth and tenth squares are marked red and blue to read easily the number of the little squares, where a is visible, and on the back side of the mica-plate there is a rough numbered division for the same purpose, sufficiently visible, because the mica is very thin.

The eye, when first looking through the double eyepiece, cannot discern whether the micrometer be placed before the right or the left eye, at least if there is not too large a difference of focus between both eyes.

The greatest usefulness will be for measurements of faint celestial objects suffering from illumination of the wires in the field; for it is a physiological fact that the left eye, for instance, may look on the sharply illuminated micrometer without affecting the perfect visibility by the right one of faint comes or satellites, as those of *Saturn* for instance, allowing thus of less aperture for such difficult work, and finishing measurement in a moment, with a single glance at the object. Finally, we can by means of it measure the position of protuberances relative to the solar equator, their height and diameters; also, by simply fixing the number of squares where they are visible and the amount, the smallest displacement of spectral lines will be likewise measurable by it.

Its use is universal for every kind of astronomical and spectroscopical work; but it also could be used for geodetical surveys, giving three coordinates, viz., x, y, and by their differences the parallax of every point taken from a stand-line (a b) of known length, from which parallax may be deduced the horizontal parallax, and therefore the distance, or the third coordinate z, for every point measured with the stereo-micrometer.

I made also use of photography for the same purpose, taking with an orthoscopic lens two views on both ends of the stand-line, and using plates, on which were formerly made photographs of a similar square micrometer from a drawing on paper or cardboard. These photographs, well dried, were covered again with a sensitive film of collodion, and oriented exactly on the same point of the landscape for every image taken. Both projections of the landscape gave x, y and x', y' for both ends (a and b) of the stand-line, and their differences the parallax of every point (or z), and the distance of the point from the optical centre of the orthoscopic lens.

The shrinkage of the collodion film, at least on albumenised plates, will have scarcely a perceptible influence on the exactness of measurement, inasmuch as it will be nearly uniform for both films, the first bearing the image of the micrometer and the second film with the photograph of the landscape being superposed on the former. It is essential to use always the same collodion, of the same thickness, and sensitised in the same bath.

Prague, 1876, *January*.

Comparison of Recent and Former Observations of B.A.C. 793, and Remarks on the alleged Variability of its Proper Motion.

By Edwin Dunkin, Esq.

The few stars which are known to have an irregular proper motion have given to this subject a peculiar interest, especially since the disturbing causes in the cases of *Sirius* and *Procyon* have been discovered. When, therefore, a suspected variability in the proper motion of so small a star as B.A.C. 793 was pointed out by Professor Smyth (*Monthly Notices*, vol. xxxv. pp. 356–61), it appeared to me interesting to inquire whether any evidence could be deduced from other sources for or against this apparent irregularity of proper motion. Professor Argelander had previously, in volume vii. of the *Bonn Observations*, discussed the proper motion of this star in a most exhaustive manner, in common with 249 others, without detecting any variability calling for especial notice. But the tables given by Professor Smyth, formed from observ tions extending over thirty years, at the Edinburgh Observatory, exhibited such a decided and gradual change in the proper motion since 1837, both in R.A. and N.P.D., that it was thought worth while to examine the few Greenwich observations of the star to ascertain whether they gave any tendency towards a confirmation of Professor Smyth's numbers. Unfortunately, this star was not observed at Greenwich after 1858, and it was subsequently to that date that the start in the Edinburgh proper motion in N.P.D. began. The materials were therefore not very good for the comparison. But by dividing the observation-groups into intervals—much too short, however, to expect even moderate accuracy—it was shown that there was some general resemblance in the resulting Edinburgh and Greenwich values for proper motion in R.A.; but in the absence of later observations, it was impossible to pronounce, from this imperfect comparison, any decided opinion on the reality of the irregular changes in the amount of the proper motion given in Professor Smyth's paper.

The materials in hand have been, however, much increased by a series of observations since made at the Royal Observatory, and, through the kind permission of the Astronomer Royal, I have been enabled to avail myself of the results of this series, consisting of ten observations of B.A.C. 793 in both elements, and seven of a small preceding neighbouring star, Weisse's Bessel, (1) II. 453, which had also been previously observed four times between 1858 and 1863, evidently by mistake for the larger star. The comparison of the places of these two stars has given a valuable and independent result for the proper motion of B.A.C. 793. I have also officially received a paper sent by Mr. Stone to the Society—inserted in the present number of the *Monthly Notices*—in which he states that in 1837 the star B.A.C. 793 was observed at the Cape Observatory fourteen times in

right ascension, and that the Cape mean observed right ascension for that year differs as much as $0^s.315$ from that determined by the Edinburgh observations, a quantity sufficient, if the Cape right ascension were substituted for that of Edinburgh, to cause most of the apparent variability to disappear. It may be remarked, however, that the Greenwich observed mean right ascension determined from one observation in 1837, and four in 1838, reduced to 1837, January 1, is nearly the mean of the Edinburgh and Cape results.

It is not necessary at present to enter into more detail than what is required to determine the resulting proper motion from a comparison of the separate means of the observations of Lalande, Piazzi, Greenwich (1837–38), Greenwich (1845–46), and Greenwich (1852–58), with the ten observations made at the Royal Observatory in the latter end of 1875 and the beginning of 1876, the mean R.A. and N.P.D. being reduced to 1876, January 1. All the Greenwich observations having been corrected for the elapsed part of the proper motion depending on the fraction of the year, the different values for proper motion in Table III. refer in each case to a time half-way between the two epochs.

In Tables I. and II. the reduced mean R.A. and N.P.D. of the star at the epoch of each catalogue are given, and also for 1876, January 1, formed by applying to the former the geometrical precessions for the mean year multiplied by the number of years between each epoch and 1876. The R.A. and N.P.D. from Lalande and Piazzi's Catalogues are the corrected places used by Argelander in volume vii. of the *Bonn Observations*.

R.A. Table I.

Catalogue.	Mean Epoch of Obs.	Mean Epoch of Cat.	No. of Obs.	Mean R.A. at Epoch of Cat. h m s	Geometrical Precession. s	Mean R.A. 1876, Jan. 1. h m s
Lalande	1794·0	1800	1	2 25 7·010	3·1577	2 29 7·000
Piazzi	1800·9	1800	7	2 25 7·900	3·1577	2 29 7·890
Greenwich	1837·0	1837	5	2 27 9·017	3·1595	2 29 12·238
Greenwich	1855·0	1855	29	2 28 8·066	3·1605	2 29 14·437
Greenwich	1876·0	1876	10	2 29 16·920	...	2 29 16·920

N.P.D. Table II.

Catalogue.	Mean Epoch of Obs.	Mean Epoch of Cat.	No. of Obs.	Mean N.P.D. at Epoch of Cat. ° ′ ″	Geometrical Precession. ″	Mean N.P.D. 1876, Jan. 1. ° ′ ″
Lalande	1794·0	1800	1	84 4 44·45	16·059	83 44 23·97
Piazzi	1800·9	1800	7	84 4 31·95	16·059	83 44 11·47
Greenwich	1845·0	1845	5	83 51 23·12	15·995	83 43 7·28
Greenwich	1855·0	1855	31	83 48 28·89	15·978	83 42 53·35
Greenwich	1876·0	1876	10	83 42 21·31	...	83 42 21·31

The annual proper motions deduced from the preceding tables are as under:

TABLE III.

Catalogues.	Mean Year for Proper Motion.	Proper Motion in R.A. s	Proper Motion in N.P.D. "
Lalande and Greenwich (1876)	1835·0	+0·1210	−1·496
Piazzi „	1838·0	+0·1202	−1·466
Greenwich (1837) „	1856·5	+0·1201	...
Greenwich (1845) „	1860·5	...	−1·483
Greenwich (1855) „	1865·5	+0·1182	−1·526

The star W.B. II. 453 having been observed several times between 1858 and 1863, the values of its proper motion have been approximately determined from a comparison of these with the recent observations to be −0ˢ·001 in R.A. and −0″·09 in N.P.D. In comparing the relative positions of this star and B.A.C. 793 at the two epochs these proper motions have been applied to the places of W.B. II. 453 for the interval between the years 1855 and 1876. The following are the observed differences between the mean R.A. and N.P.D. of the two stars:

		Diff. of R.A. s	Diff. of N.P.D. "
B.A.C. 793 − W.B. II. 453	1855 Jan. 1	+37·281	−13·28
„ „	1876 „	+39·777	−44·76
Excess of B.A.C. 793 in 21 years		+ 2·496	−31·48

From the direct comparison, therefore, of the observed places of these two stars we obtain the following independent values of the proper motion of B.A.C. 793, in both elements, which are probably not far from the true ones:

	Proper Motion in R.A. s	Proper Motion in N.P.D. "
1855, Jan. 1, to 1876, Jan. 1	+0·1189	−1·499

These values are almost identical with those for the corresponding group in Table III.

Without entering into further detail, I think that the evidence given above is sufficient to warrant the conclusion that the proper motion of B.A.C. 793 has not really changed during the present century. The wonder is that the results for the different groups agree so well, considering that Lalande's place depends only on one observation in each element, and the com-

paratively inferior instruments with which both Lalande's and Piazzi's observations were made. The proper motion in R.A. certainly shows a gradual diminution in the value from group to group, but by a quantity so minute that it probably owes its origin more to accident than to any other cause. If there had been any real changes similar to those indicated by the Edinburgh observations, they must have appeared in the resulting Greenwich values, which the excellent series of observations lately made at the Royal Observatory has enabled me to determine.

Kenwyn, Kidbrooke Park Road, Blackheath,
1876, *March* 7.

On a Supposed Variability of the Proper Motion of B.A.C. 793. By E. J. Stone, Esq., F.R.S., Her Majesty's Astronomer, Cape of Good Hope.

In the *Monthly Notices* for May 1875 there appeared an interesting paper by Professor C. Piazzi Smyth, in which an attempt is made to prove that the proper motions of the star B.A.C. 793 have varied sensibly since 1837. On reading the paper, I was much struck with the fact that the whole argument in favour of the variability of the proper motion turns upon the extreme accuracy of the Edinburgh observations made in 1837. I find that the star B.A.C. 793 was observed at the Cape no less than fourteen times in Right Ascension in the year 1837. Unfortunately, it was not also observed in North Polar Distance.

If we assume the proper motion in Right Ascension to be $0^s{\cdot}120$, then we have:

1837 Jan. 1 R.A. of B.A.C. 793 = $2^h\ 27^m\ 9^s{\cdot}155$.

The number of observations upon which this result depends is 14, and the fraction of the year for which proper motion has been applied is 0·89.

It will be seen that the Right Ascension deduced from the Cape observations differs considerably from the result of the three Edinburgh observations.

If we bring up the Right Ascension deduced from the Cape observations with the proper motion $+0^s{\cdot}120$, the following table will exhibit the excess of the computed results over the observed result given in Professor Smyth's paper :—

	Excess of Computed R.A. s	No. of Obs.
1851	−0·07	5
1852	−0·06	4
1855	−0·00	5
1858	+0·01	6
1861	+0·05	2
1862	+0·06	3
1863	+0·03	3
1865	+0·01	3
1866	+0·02	1
1867	+0·03	3

The evidence in favour of the supposed variability of the proper motion in Right Ascension appears to me but very slight indeed.

1876, *Jan.* 20.

On the Proper Motions of the Two Components of the Binary System α Centauri.

By E. J. Stone, Esq., F.R.S., Her Majesty's Astronomer, Cape of Good Hope.

In the formation of the Cape General Catalogue of Stars for 1860, I adopted $-0^s\cdot470$ and $-0''\cdot83$ for the *common* proper motions of the stars α_1 and α_2 *Centauri* in R.A. and N.P.D. respectively. In the Melbourne General Catalogue of Stars for 1870, the adopted *common* proper motions are $-0^s\cdot480$ and $-0''\cdot49$. Attention has been called to the discrepancy between these adopted values, particularly in N.P.D., in *Nature* of 1874, November 4. The writer appears to consider the Melbourne value the more correct, and that the Cape value depends upon Lacaille's declination. The point here raised is of some importance. I have, therefore, collected together the data available to me, and discussed them in the present paper.

The following observations will be made use of:—

α *Centauri.*

(1st magnitude).

	Epoch.	R.A.			No. of Obs.	N.P.D.			No. of Obs.
		h	m	s		°	′	″	
1	1750	14	22	49·9		149	47	8	
2	1825	14	27	(46·77)		150	6	19·1	171
3	1830 F	14	28	7·47	11	150	7	32·68	8
4	1830 J	14	28	7·98	21	150	7	35·40	13
5	1833	14	28	19·74	27	150	8	20·9	20
6	1840	14	28	47·45	189	150	10	7·10	47
7	1860	14	30	7·23	2	150	15	19·55	160
8	1870	14	30	47·07	20	150	17	53·93	20
9	1871					150	18	9·72	32
10	1872					150	18	24·64	3
11	1875	14	31	7·07	4				

α *Centauri.*

(2·3 magnitude.)

	Epoch.	R.A.			No. of Obs.	N.P.D.			No. of Obs.
		h	m	s		°	′	″	
1	1750	14	22	48·2		149	47	24	
2	1825	14	27	(45·04)		150	6	37·4	44
3	1830 F								
4	1830 J	14	28	6·44	7	150	7	51·8	7
5	1833	14	28	18·22	26	150	8	35·5	17
6	1840	14	28	46·09	180	150	10	20·78	33
7	1860	14	30	7·06	3	150	15	18·68	3
8	1870	14	30	47·50	10	150	17	43·69	13
9	1871					150	18	0·11	29
10	1872					150	18	15·38	3
11	1875	14	31	7·70	4				

The observations in the first group are Lacaille's; the second contains Brisbane's Observations; the fourth, Johnson's St. Helena Observations. The observations in the eighth group are taken from the Melbourne Catalogue; the other observations are all Cape Observations. I have no confidence in Brisbane's Right Ascensions, and I have not used them in the present enquiry. Taylor's Catalogue is not available: the observations extend over many years, and the mean year of observation is not given in the Catalogue.

There are two ways in which these observations may be discussed with reference to the proper motions of the stars. If the stars are so far apart from each other that their common gravitation does not affect, by quantities yet observationally sensible, the proper motions existing at any epoch, there is no legitimate ground for an *à priori* assumption of any proper motion common to the stars. The proper motions of each star must be determined in the usual way, and applied to the reductions of the place of the star from one epoch to another. If on the other hand, we assume that the stars are so near to each other that the effects of their common gravitation are observationally sensible, we have no right to expect that the proper motions determined in the usual way for each star will be constant. The only legitimate assumption is, that the proper motion of their common centre of gravity may, from our experience in the case of other stars, be sensibly constant. I will discuss the observations on both assumptions.

The proper motions of the two stars in R.A. and N.P.D. will be represented by x_1, y_1, x_2, y_2. The true Right Ascensions and North Polar Distances for 1870 will be assumed to be:

h	m	s	°	′	″
14	30	$47{\cdot}07 + a_1$,	150	17	$53{\cdot}93 + d_1$
14	30	$47{\cdot}50 + a_2$,	150	17	$43{\cdot}69 + d_2$.

On account of the existence of systematic errors, some limit must be fixed to the weight which can be assigned to a group of observations. I have fixed upon 36 as the extreme weight. Up to that limit I roughly weight the residuals in proportion to the number of observations in each group. The following are the equations of condition for each star:—

1st Magnitude Star.

Group.		R.A. s	$\sqrt{\omega}$	C.−O. s
1	$a_1 - 120\,x_1 =$	57·69	1	+2·48
3	$a_1 - 40\,x_1 =$	20·47	5	−0·30
4	$a_1 - 40\,x_1 =$	19·96	4	+0·21
5	$a_1 - 37\,x_1 =$	18·81	5	−0·14
6	$a_1 - 30\,x_1 =$	15·17	6	0·00
7	$a_1 - 10\,x_1 =$	5·17	1	0·00
8	$a_1 - 0\,x_1 =$	0·00	5	+0·17
11	$a_1 + 5\,x_1 =$	−2·53	2	+0·20

$$133\,a_1 - 3755\,x_1 = +1900{\cdot}22$$
$$-3755\,a_1 + 146825\,x_1 = -74052{\cdot}35$$
$$a_1 = +0^s{\cdot}172, \quad x_1 = -0^s{\cdot}500.$$

2·3 Magnitude Star.

		R.A. s	$\sqrt{\omega}$	C.−O. s
1	$a_2 - 120\,x_2 =$	55·56	1	−0·64
4	$a_2 - 40\,x_2 =$	18·50	3	−0·30
5	$a_2 - 37\,x_2 =$	16·86	5	−0·04
6	$a_2 - 30\,x_2 =$	13·38	6	+0·23
7	$a_2 - 10\,x_2 =$	4·57	2	−0·14
8	$a_2 - 0\,x_2 =$	0·00	4	−0·16
11	$a_2 + 5\,x_2 =$	−2·33	2	−0·13

$$95\,a_2 - 2505\,x_2 = 1134{\cdot}20$$
$$-2505\,a_2 + 95925\,x_2 = -43602{\cdot}50$$
$$a_2 = -0^s{\cdot}164, \quad x_2 = -0^s{\cdot}459.$$

The following are the equations of condition in N.P.D. :—

1st Magnitude Star.

	N.P.D.		s	$\sqrt{\omega}$	C.−O.
1	$d_1 - 120\,y_1 =$		84·13	1	−23·67
2	$d_1 - 45\,y_1 =$		22·99	5	− 1·15
3	$d_1 - 40\,y_1 =$		19·17	4	+ 0·09
4	$d_1 - 40\,y_1 =$		16·39	3	+ 2·87
5	$d_1 - 37\,y_1 =$		16·65	4	+ 1·07
6	$d_1 - 30\,y_1 =$		10·91	5	+ 3·20
7	$d_1 - 10\,y_1 =$		4·50	1	− 0·69
8	$d_1 - 0\,y_1 =$		0·00	4	− 1·34
9	$d_1 + y_1 =$		−0·08	5	− 1·78
10	$d_1 + 2y_1 =$		−1·03	2	− 1·34

$$138\,d_1 - 3564\,y_1 = 1650{\cdot}64$$
$$-3564\,d_1 + 149570\,y_1 = -72223{\cdot}09$$
$$d_1 = -1''{\cdot}34, \quad y_1 = -0''{\cdot}515$$

2·3 Magnitude Star.

		$\sqrt{w}$	C.–O.
1	$d_2 - 120\ y_2 = 110{\cdot}37$	1	+ 19·42
2	$d_2 - 45\ y_2 = 51{\cdot}53$	5	— 1·39
4	$d_2 - 40\ y_2 = 45{\cdot}81$	3	— 0·98
5	$d_2 - 37\ y_2 = 41{\cdot}49$	4	+ 0·15
6	$d_2 - 30\ y_2 = 34{\cdot}83$	5	— 0·62
7	$d_2 - 10\ y_2 = 13{\cdot}87$	2	— 0·90
8	$d_2 - 0\ y_2 = 0{\cdot}00$	3	+ 2·35
9	$d_2 + y_2 = 0{\cdot}55$	5	+ 0·74
10	$d_2 + 2\ y_2 = -0{\cdot}05$	2	+ 0·28

$$118\ d_2 - 2954\ y_2 = 3414{\cdot}53$$
$$-2954\ d_2 + 124270\ y_2 = 138933{\cdot}28$$
$$d_2 = +2''{\cdot}35, \quad y_2 = -1''{\cdot}062$$

The values of the proper motions of the principal star agree closely with the adopted *common* proper motions of the Melbourne Catalogue. The means of the proper motions of the two stars agree closely with the adopted *common* proper motions of the Cape Catalogue.

If, for clearness of conception of the differences between these proper motions, especially in N.P.D., we place side by side the proper motions that would result from a comparison of the last group with each of the other groups whose epoch differs from its epoch by more than ten years, we have as follows :—

Proper Motions in N.P.D.

	1750.	1825.	1830.	1833.	1840.	1860.
	″	″	″	″	″	″
1 Mag *	−0·698	−0·511	{−0·481 / 0·412}	−0·453	−0·373	−0·461
2·3 Mag *	−0·905	−1·098	−1·092	−1·065	−1·090	−1·160
Mean P.M.	−0·802	−0·804	−0·770	−0·759	−0·732	−0·810

If therefore we attach the slightest weight to Lacaille's observations, the physical connexion of the two stars is at once established, and the course adopted in the Cape Catalogue is sensibly correct. But if this physical connexion is not admitted, the adoption of a common proper motion of $-0''{\cdot}50$ in N.P.D. for the two stars is certainly not satisfactory. The adopted proper motion should be $-0''{\cdot}52$ for the 1st magnitude star, and $-1''{\cdot}06$ for the 2·3 magnitude star. An inspection, however, of the residuals shows, I venture to think, that the assumption of a constant proper motion for either star is not a true assumption, and that the physical connexion of the system must be admitted.

I therefore pass to the second assumption. If m_1 and m_2 denote the masses of the two stars, we may show that

$$\frac{m_1}{m_1+m_2}x_1 + \frac{m_2}{m_1+m_2}x^2 \text{ and } \frac{m_1}{m_1+m_2}y_1 + \frac{m_2}{m_1+m_2}y_2$$

are constant when terms of the second order are neglected. To the same order of approximation these expressions in fact denote the proper motions of the centre of gravity of the system in R.A. and N.P.D. If the data were sufficiently accurate and well distributed, it should be possible to infer the ratio of the masses $m_1 : m_2$ from the condition that this ratio rendered the proper motions of the centre of gravity constant. The data at present available are not perhaps sufficient for such a delicate inquiry, but it will be seen that an assumption of equality between the masses does render the proper motions of the centre of gravity very accordant. As this assumption appears to satisfy the conditions better than one dependent upon their brightness, I have provisionally adopted it.

Assuming therefore $m_1 = m_2$, and denoting the R.A. and N.P.D. of the centre of gravity at the epoch 1870 by

$$14^h\ 30^m\ 47^s{\cdot}285 + a$$
$$150^\circ\ 17'\ 48''{\cdot}81 + d$$

and the proper motions of the centre of gravity by x and y, we have the following equations of condition.

R.A. Observations.

Epoch.		$\sqrt{w}$	C.−O.
			s
1750	$a - 120\,x = 56{\cdot}63$	1	+0·56
1830	$a - 40\,x = 19{\cdot}49$	$\sqrt{5}$	−0·38
1833	$a - 37\,x = 17{\cdot}84$	$\sqrt{13}$	−0·16
1840	$a - 30\,x = 14{\cdot}28$	$\sqrt{36}$	+0·07
1860	$a - 10\,x = 4{\cdot}87$	1	−0·04
1870	$a - 0\,x = 0{\cdot}00$	$\sqrt{8}$	+0·07
1875	$a + 5\,x = -2{\cdot}43$	$\sqrt{2}$	+0·12

From which we derive the following equations for the determination of a and x:

$$66\,a - 1881\,x = 900{\cdot}09$$
$$-1881\,a + 72747\,x = -34770{\cdot}04;$$

which give:

$$a = +0^s{\cdot}072$$
$$x = -0^s{\cdot}476.$$

It is with these values that the residuals given in the column (C.−O.) have been formed.

N.P.D. Observations.

Epoch.		$\sqrt{w}$	O.–C.
	$''$		$''$
1750	$d - 120\,y = 97{\cdot}25$	1	−0·28
1825	$d - 45\,y = 37{\cdot}26$	6	−0·67
1830	$d - 40\,y = 32{\cdot}49$	2	+0·08
1833	$d - 37\,y = 29{\cdot}07$	3	+1·08
1840	$d - 30\,y = 22{\cdot}88$	4	+1·64
1860	$d - 10\,y = 9{\cdot}19$	2	−0·77
1870	$d - 0\,y = 0{\cdot}00$	3	+0·37
1871	$d + y = 0{\cdot}24$	4	−0·68
1872	$d + 2\,y = -0{\cdot}54$	1	−0·70

The equations for the determination of d and y are:

$$96\,d - 2735\,y = 2236{\cdot}34$$
$$-2735\,d + 120841\,y = -98257{\cdot}15$$

which give:

$$d = +0''{\cdot}366$$
$$y = -0''{\cdot}805$$

These values have been used in the formation of the residual errors.

The residuals for the N.P.D. observations about 1833–1840 are large; but it may be mentioned that the observations in the groups 1833–1840 were made with the same instrument, and that, although the adopted zenith-points have been determined from reflexion and direct observations of stars, and that the observations of *α Centauri* must, from their number, have had considerable weight in the formation of the adopted zenith-points, yet a discordance of about $1''{\cdot}6$ still exists between the direct and reflexion results for *α Centauri*. The residuals are, however, certainly much more satisfactory, especially in N.P.D., than the residual errors resulting from the assumption of the independence of the two stars. It is not, therefore, the use of Lacaille's observations which give rise to the large proper motion in N.P.D. adopted in the Cape Catalogue, for but little weight has been assigned them. If we compare the last Cape observation group for 1872 with the earlier observations, the following would be the separate values of the common proper motion in N.P.D.:

1750.	1825.	1830.	1833.	1840.	1860.
$-0''{\cdot}801$	−0·804	−0·786	−0·759	−0·732	+0·810

These results are as accordant as could be expected, and appear to justify as a close approximation to the truth the

assumption of $m_1 = m_2$. It will be seen that the proper motions deduced from the centre of gravity of the system, or the common proper motions of the two stars, viz., $-0^s.476$ and $-0''.805$, are nearly the same as those adopted in the Cape Catalogue, 1860. If common proper motions be adopted for the two stars, the results of the Cape Catalogue are substantially correct.

Occultation of the Pleiades observed at Madras, on January 7th, 1876.

(*Communicated by N. R. Pogson, Esq., Director of the Observatory*).

Star.	Phenomenon.	Madras M.T. h m s	Observer.
16 Tauri (Celæno)	Disap.	12 43 50·9	N.R.P.
" " "	"	12 43 51·0	E.I.P.
17 Tauri (Electra)	"	12 47 28·8	N.R.P.
" " "	"	12 47 29·1	E.I.P.
19 Tauri (Taygeta)	"	13 7 43·1	N.R.P.
" " "	"	13 7 43·1	E.I.P.
20 Tauri (Maia)	"	13 14 9·6	N.R.P.
" " "	"	13 14 18·0	E.I.P.
Bessel's Anonyma 8	"	13 23 1·1	N.R.P.
" " "	"	13 23 1·5	E.I.P.
Bessel's Anonyma 9	"	13 24 14·7	N.R.P.
Bessel's Anonyma 10	"	13 28 3·7	E.I.P.
22 Tauri	"	13 35 47·3	N.R.P.
" "	"	13 35 47·0	E.I.P.
21 Tauri (Asterope)	"	13 40 27·1	N.R.P.
" " "	"	13 40 26·7	E.I.P.
Bessel's Anonyma 12	"	13 54 30·0	N.R.P.
" " "	"	13 54 32·5	E.I.P.
24 Tauri	"	13 58 49·2	N.R.P.
η Tauri (Alcyone)	"	14 3 48·3	N.R.P.
" " "	"	14 3 47·8	E.I.P.
20 Tauri (Maia)	Reap.	14 12 27·2	N.R.P.
" " "	"	14 12 32·4	E.I.P.
Bessel's Anonyma 29	Disap.	14 19 10·3	N.R.P.
η Tauri (Alcyone)	Reap.	14 38 24·3	N.R.P.
" " "	"	14 38 15·2	E.I.P.

The preceding Observations were made, as initialled, by Mr. Norman R. Pogson, with the Smythian 5-ft. telescope, by Tulley,

power 74; and by his daughter and chief assistant, Miss E. Isis Pogson, with the Lerebours & Secretans' Equatoreal, power 63. The former used a mean-time chronometer; the latter a sidereal clock. All the disappearances at the Moon's dark limb were sudden and satisfactory, but an error of ten seconds, due to miscounting, appears to have been made by one of the Observers in the case of *Maia*. The Moon set at $15^h\ 3^m$, and the sky being hazy near the horizon, the reappearances were very uncertain, especially that of *Alcyone*, which was certainly not noted by N. R. P. until much too late. The broad hyperbolic boundary of the nebulosity in the south-west of the *Pleiades* is always easily traceable here with the Lerebours' Equatoreal, and the contrast between the greyish-white sky-ground around and *s p* of *Merope* with the deep blue background near *Alcyone* is very striking on a fine moonless night. In the absence of moonlight, besides the six well-known and conspicuous stars, *Celæno*, the combined light of *Asterope* and 22 *Tauri* as one object, and *Pleione*, distinct from *Atlas*, are all clearly discernible to any tolerably good unaided sight which is up to seeing *Uranus*, *Vesta* in opposition, 13 *Messier* in *Hercules*, or separating 4 and 5 *Lyræ* without optical aid.

Micrometer-Measures of Saturn's Satellites, made at the Royal Observatory, Greenwich, in the year 1875.

(*Communicated by the Astronomer Royal.*)

The observations were made with the Great Equatoreal, using a power of 285 applied to the Position Micrometer. The measures of distance are the means of the distances from the satellite to the near and distant limbs of *Saturn*, two moveable webs being brought simultaneously on the satellite and on each limb of *Saturn* alternately; the position-angles prior to September 21 are the means of those found by making a fixed web (at right angles to the other), bisect the satellite, and touch the limb of *Saturn* on the two sides alternately. On September 21 two webs were inserted parallel to the fixed web, and at such a distance apart that the two new webs could be made to touch the limbs of *Saturn* at the same time that the middle web bisected the satellite; each of the position-angles given is the mean of those found in reversed positions of the micrometer, and is measured from the N. point in the direction N.E.S.W. The observations were usually made with the illuminated wires in a dark field.

The initials W. C., M., and J., are those of Messrs. Christie, Maunder and Jenkins.

	Greenwich Sidereal Time of Obs. of Distance.	Observed Distance.	Greenwich Sidereal Time of Obs. of Position-Angle.	Observed Position-Angle.	Observer.
		Iapetus.			
1875.	h m s	′ ″	h m s	° ′	
Sept. 14	20 45 45	3 11·50	20 54 30	94 49	W. C.
17	20 37 40	1 8·19	20 49 45	106 42	J.
,,	22 31 40	1 4·18	22 37 25	109 13	
20	20 17 10	1 5·25	20 24 50	252 41	W. C.
29	20 58 5	6 31·98	21 3 20	268 7	M.
,,	21 15 55	6 34·70			
Oct. 2	22 1 10	7 51·73	21 30 15	269 22	J.
5	21 52 15	8 36·44	22 20 40	269 41	,,
,,	22 41 45	8 37·34			
6	20 22 40	8 45·43	21 10 15	270 20	,,
,,	21 14 20	8 46·94			
11	21 42 45	8 55·14	21 48 15	270 50	M.
,,	22 0 25	8 50·14			
12	21 49 20	8 39·13	21 49 56	270 41	W. C.
,,	22 0 55	8 40·41			
16	20 49 5	7 32·46	20 58 25	271 53	J.
,,	20 58 45	7 34·02			
21	21 42 35	5 6·68	21 44 35	273 45	
25	21 37 0	2 38·90	21 54 50	277 26	
,,	21 53 40	2 38·54			
Nov. 4	21 47 10	3 59·48	22 0 15	86 23	,,
,,	21 59 15	4 2·85			
8	22 18 55	5 29·83	22 26 20	85 38	,,
,,	22 25 50	5 30·02			
		Titan.			
Sept. 14	19 39 45	2 38·88	19 46 20	105 54	W. C.
,,	19 53 15	2 37·21	19 58 35	105 49	
15	21 31 25	1 45·41	21 37 30	119 17	J.
,,	22 26 15	1 45·26	22 30 45	118 23	
17	19 53 15	56·21	19 56 5	224 44	,,
,,	21 56 50	59·95	21 59 50	230 32	
18	21 24 10	1 53·18	21 31 10	257 30	W. C.
20	21 0 5	2 59·37	20 55 20	273 58	,,
27			21 15 50	89 38	M.

1875.	Greenwich Sidereal Time of Obs. of Distance. h m s	Observed Distance. ′ ″	Greenwich Sidereal Time of Obs. of Position-Angle. h m s	Observed Position-Angle. °	Observer.
Sept. 28	22 2 10	3 8·42			
29	20 24 55	3 3·95	20 36 5	100 18	M.
,,	20 47 50	3 3·13			
30	20 33 55	2 33·51	20 46 25	106 35	J.
,,	20 48 25	2 32·68			
Oct. 2	20 33 0	55·59	21 14 10	152 47	,,
,,	21 49 50	52·20			
5	21 35 0	2 34·75	21 59 50	269 24	,,
,,	22 15 15	2 38·83			
6	20 15 25	2 55·93	20 41 5	275 22	,,
,,	20 59 40	2 56·25			
11	21 27 35	1 12·73	22 0 15	68 33	M.
,,	22 35 20	1 16·23			
12	21 5 0	2 4·86	21 51 45	81 22	W. C.
,,	22 41 55	2 8·75			
16	21 42 40	2 27·02	21 49 10	108 0	J.
,,	21 49 10	2 28·28			
21	21 36 45	2 32·12	21 38 50	268 32	,,
25	20 57 35	1 28·33	21 3 45	302 11	,,
,,	21 4 0	1 28·03			
Nov. 4	21 22 10	58·70	21 30 55	229 41	,,
,,	21 30 25	58·95			
8	21 42 10	2 41·42	21 57 40	80 53	,,
,,	22 6 5	2 42·40			
15	21 28 30	2 55·83	21 38 5	95 46	M.
,,	21 51 35	2 33·01)			
		Rhea.			
Sept. 14	20 10 5	46·29	20 20 30	76 18	W. C.
,,	22 47 0	55·22	22 37 0	79 34	
15	21 20 15	1 14·01	21 25 35	102 40	J.
,,	22 13 5	1 11·68	22 19 40	101 49	
17	19 40 20	1 21·71	19 45 30	275 24	,,
,,	21 45 20	1 23·06	21 50 0	278 49	
18	21 3 40	21·45	21 16 0	340 48	W. C.
20	20 49 0	42·15	20 43 55	119 53	,,
27			20 49 5	326 30	M.
28	21 55 10	1 16·02	21 18 40	90 [illegible]	

1875.	Greenwich Sidereal Time of Obs. of Distance. h m s	Observed Distance. "	Greenwich Sidereal Time of Obs. of Position-Angle. h m s	Observed Position-Angle. ° ′	Observer.
Sept. 29	20 16 30	48·21	20 30 45	116 5	M.
„	20 39 10	49·53			
30	21 49 55	1 2·34	21 55 20	263 56	J.
Oct. 2	20 18 5	36·04	21 2 45	70 18	„
„	21 39 45	41·78			
5	21 28 50	1 17·97	21 52 30	274 21	„
„	22 8 55	1 19·48			
6	20 6 15	22·16	20 32 45	313 32	„
„	20 51 5	29·00			
11	21 12 10	34·32	21 49 30	69 24	M.
„	22 30 5	39·09			
12	21 12 30	1 16·49	21 48 50	99 45	W. C.
„	22 28 40	1 15·75			
16	20 23 40	1 5·51	20 31 30	86 45	J.
„	20 37 10	1 7·35			
21	21 31 25	1 17·25	21 33 35	97 56	„
25	20 44 35	1 3·07	20 50 45	85 32	„
„	20 51 5	1 3·08			
Nov. 4	21 35 55	57·07	21 40 35	107 54	„
„	21 41 5	57·58			
8	21 47 25	2 13·59	21 56 45	95 0	„
„	21 56 50	1 55·24			
15	21 37 10	1 10·75	21 46 55	285 4	M.
„	21 59 45	1 11·07			

Dione.

Sept. 14	21 6 55	24·98	21 13 25	120 30	W. C.
„	22 31 0	23·02	22 22 0	129 11	
17	21 10 5	14·98	21 18 55	167 24	J.
18	21 40 5	38·83	21 50 55	292 58	W. C.
20	20 34 40	54·78	20 28 30	259 7	„
29	21 59 0	35·84	22 2 45	294 15	M.
„	22 5 25	33·63			
30	21 14 20	56·19	21 35 20	97 13	J.
„	21 33 50	56·05			
Oct. 5	21 43 0	30·61	22 10 30	78 28	„
„	22 27 45	33·30			

1875.	Greenwich Sidereal Time of Obs. of Distance. h m s	Observed Distance. "	Greenwich Sidereal Time of Obs. of Position-Angle. h m s	Observed Position-Angle. ° ′	Observer.
Oct. 6	20 39 30	26·90	21 10 30	120 57	J.
,,	21 35 55	23·67			
11	21 6 10	54·12	21 40 20	98 24	M.
,,	22 22 50	57·32			
12	21 34 25	42·54	21 50 55	265 29	W. C.
,,	22 12 0	45·43			
16	21 14 10	32·44	21 25 10	77 56	J.
,,	21 27 0	33·16			
21	21 50 40	32·62	21 53 55	299 55	,,
25	21 12 20	43·28	21 20 55	93 49	,,
,,	21 21 25	44·28			

Tethys.

Sept. 14	21 21 40	22·38	21 29 30	254 51	W. C.
,,	21 47 45	23·92	21 39 45	255 5	
17	20 4 45	33·37	20 10 15	85 27	J.
,,	22 8 40	39·14	22 13 40	90 14	
18	22 3 40	24·36	22 16 10	272 38	W. C.
20	20 0 25	44·88	20 9 15	273 23	,,
,,	20 4 55	47·48			
Oct. 2	21 19 40	23·08	21 23 0	68 54	J.
5	21 22 0	39·53	21 46 20	270 51	,,
,,	22 1 20	40·99			
6	20 30 50	41·99	21 1 40	90 32	,,
,,	21 27 30	43·13			
11	21 18 45	39·32	21 42 50	286 13	M.
,,	22 11 50	37·50			
12	21 21 45	33·55	21 20 0	107 14	W. C.
21	21 25 20	32·17	21 50 35	85 10	J.
,,	22 4 5	30·24			
25	22 12 25	38·77	22 21 30	111 13	,,
,,	22 20 25	39·36			
Nov. 8	21 37 15	33·16	22 39 25	266 17	,,
,,	21 42 10	36·40			
15	22 45 45	29·91	22 46 15	110 12	M.
,,	22 51 0	27·58			

Notes.

September 14. *Saturn* was very tremulous and diffused at times. *Iapetus*, *Dione*, and *Tethys* were very faint, and were observed in a slightly illuminated field. The belt of *Saturn* was very conspicuous, but the colour was scarcely so marked as when seen a week previously. The curvature of the shadow of the ball on the ring was very well seen, the definition being occasionally very good.

September 15 and 17. The measures were made with great difficulty.

September 18. Sky very hazy; the observations were difficult, but the definition of the planet was very good for a few moments at a time. The belt was again very conspicuous and reddish, and the planet appeared brighter than the ring where it crossed the ball. The shadow on the ring was curved as on September 14.

September 20. Sky rather hazy.

September 28. *Saturn* very tremulous.

September 29. *Dione* was exceedingly faint and difficult to measure, and was only seen at long intervals. All the observations were made with the wires illuminated on a dark field. *Saturn* was occasionally well defined, but in general the limbs were diffused.

September 30. The planet tremulous.

October 2. At the first observation of *Titan* the image of *Saturn* was tremulous, otherwise it was very good.

October 5. The planet tremulous at the second observation of *Titan*; *Dione* very faint.

October 6. *Dione* and *Tethys* very faint.

October 16. The first measures of *Titan*, *Rhea*, and *Dione* were made under favourable circumstances; but before the second series of measures the limbs of *Saturn* became very tremulous, and *Tethys*, especially, was difficult to measure owing to its faintness.

October 12. *Iapetus*, *Dione*, and *Tethys* faint. The illuminated wires on a dark field were used throughout the observations.

October 16. *Saturn* very tremulous; *Dione* very faint.

October 17. *Dione* very faint; the image of the planet good.

October 25. Sky rather misty; *Dione* and *Tethys* were very faint, and the planet's limbs much diffused.

November 4. Sky rather hazy; *Iapetus* faint.

November 8. *Iapetus* and *Tethys* faint; *Titan* and *Rhea* observed through thin cloud.

November 15. *Tethys* very faint; *Saturn* also was faint, but free from tremor in the first series of measures. In the second series the planet was diffused and tremulous.

Observations of the November Meteors, made at the Royal Observatory, Greenwich, in the Year 1875.

(*Communicated by the Astronomer Royal.*)

Greenwich Mean Solar Time 1875.	Apparent size of Meteor in Star Magnitude.	Observer.	Path of Meteor with reference to the Stars.	No. for Reference.
d h m s				
Nov. 13 13 39 10±	> 1	E.	From region of upper part of *Cancer* moved towards zenith. Observed through a break in the clouds. [Very cloudy night throughout.]	1
14 12 53 50	> 1	N.	Moved from direction of δ *Draconis* towards α *Cygni*. Estimated length of path = 6°	2
„ 13 2 40	2	G.	Shot downwards from α *Ursæ Majoris*, and disappeared between γ and δ *Ursæ Majoris*, but nearer to δ *Ursæ Majoris*	3
„ 13 48 38	> 1	N.	From a point about 5° below γ *Ursæ Majoris* fell vertically, passing almost midway between η *Ursæ Majoris* and α *Canum Venaticorum*. Estimated length of path = 16°	4
„ 14 14 20	1	G.	Shot from α *Orionis* towards *Sirius*	5
„ 14 31 27	2	N.	From direction of ε *Leonis* passed across ζ *Hydræ*. Estimated length of path = 5°	6
„ 14 32 39	2	N.	Passed across α *Orionis* towards γ *Orionis*. Estimated length of path = 6°	7
„ 14 46 13	1	N.	Appeared at a point about 5° below μ *Ursæ Majoris* and about 8° to right of ψ *Ursæ Majoris*. [Very short motion = 0°·5.]	8
„ 14 46 49	1	N.	From direction of γ *Ursæ Minoris* passed across ι *Draconis*. Estimated length of path = 10°	9
„ 14 48 35	2	N.	From direction of δ *Leonis* passed about 10° below α *Canum Venaticorum*. Estimated length of path = 12°	10
„ 14 49 17	1	N.	From a point about 10° below *Regulus* fell at an angle of 30° from vertical to left: disappeared about 15° to left of α *Hydræ*	11
„ 15 9 41	1	G.	Shot from about midway between α and β *Ursæ Majoris* towards κ *Draconis*	12

Greenwich Mean Solar Time 1875.	Apparent size of Meteor in Star Magnitude.	Observer.	Path of Meteor with reference to the Stars.	No. for Reference.
d h m s				
Nov. 14 15 15 1	2	G.	Appeared near *α Orionis*, and disappeared near *β Orionis*	13
„ 15 21 36	1	G.	Shot from *θ Geminorum* towards *Castor*	14
„ 15 26 51	1	G.	Shot from *ε Ursæ Majoris* towards *η Ursæ Majoris*	15
„ 15 30 57	2	N.	Moved from direction of a point midway between *η Ursæ Majoris* and *α Canum Venaticorum* towards *γ Boötis*. Estimated length of path = 5°	16
„ 15 36 40	2	N.	From direction of *γ Ursæ Majoris* towards *ψ Ursæ Majoris*. Estimated length of path = 5°	17
„ 15 41 34	>1	N.	Center of path about 10° to right of *Sirius*, moving from direction of *α Cancri* towards *ε Canis Majoris*. Estimated length of path = 8°	18
„ 15 58 52	1	N.	Center of path 15° below *α Hydræ*, moving from direction of *Regulus*. Estimated length of path = 5°	19
„ 16 3 7	3	G.	Shot from *γ Geminorum*, at an angle of 45° towards west	20
„ 16 9 33	2	G.	Shot from *Castor* towards *γ Geminorum*	21
„ 16 11 24	1	G.	Shot from *Aldebaran* towards *γ Orionis*	22
„ 16 14 22	2	G.	Shot from *Procyon* towards *Sirius*	23
„ 16 24 32	1	G.	Shot from *Sirius* towards *β Canis Majoris*	24
„ 16 43 3	2	G.	Shot from *ζ Draconis* towards *β Draconis*	25
„ 16 49 3	1	N.	From direction of *α Canum Venaticorum*, passed about 2° N. of *Arcturus*. Estimated length of path = 12°	26

As regards colour, Nos. 2 and 6 were recorded as being "white"; Nos. 3 to 5 and 7 to 26 were noted as "bluish white"; Nos. 1, 4, and 18 were considered to be equal in magnitude to the planet *Jupiter*.

The meteors Nos. 1, 2, 6, 7, 10, 11, 12, 13, 18, 19, 23, and 24 were from the *Leo* radiant; probably No. 20 also. The remaining meteors were from other radiants. The observations were all made in bright moonlight, consequently only, comparatively speaking, large meteors would be seen.

The initials E., N., and G. are those of Mr. Ellis, Mr. Nash, and Mr. Greengrass.

Royal Observatory, Greenwich,
1876, *March* 8.

Abstract of Prof. Christian Mayer's (of Heidelberg) Vertheidigu neuer Beobacht. Gruendliche von Fixstern Trabanten entde in der Mannheim. Sternwarte. Mannh. 1778, 8vo., pp. 30 2 plates. By S. M. Drach, Esq.

This almost forgotten little work contains a reference to t author's first proposal at the Mannheim Academy (on 17th Oc 1777) of observations of Binary Star Systems, before Sir W Herschel's discovery of *Uranus*. I first heard of it in Mädler *Populär Astron.* (*Doppelst.*, Art. 205, ed. 1841). The Roy Society, and British Museum (1395 e), each possess a cop Berlin has not yielded me a copy for presentation to the Roy Astronomical Society, and my two MS. versions, given to M Williams for our Society, seem to have been lost in the confusio of moving—a fate that also overtook Reich's first Cavendis Experiments in 1828–9, and possibly other fugitive tracts.

The author was furnished with London-made instrument was supported in his views by Maskelyne and La Caille, versu the vituperative opposition of Father Hell of Vienna. The fir portion is a reprint of newspaper articles—Mayer, in *Mannhei Zeitung* (No. 84, Oct. 20, 1777; Nos. 93–4, Nov. 20–24, 1777 No. 102, Dec. 22, 1777): and Hell, in *Wiener Diarium* (No. 9 Nov. 8, 1777; No. 99, Dec. 10, 1777; No. 102, Dec. 20, 1777

The first is an account of 100 new fixed star satellites (f. ss. observed January 30, 1776, to September 14, 1777, by Mayer an his assistant John Mezger, beginning with *Arcturus and its* 1 *Satellites* (comes).

Hell wrote in 1759 to Paris that said satellites are only sma fixed stars; and that Mayer and Mezger's small variations ha been noticed by Tycho Brahé.

Mayer keeps to the word *comes*; refers to Riccioli's *Almages* t. 1, bk. 7, ch. 3; to Flamsteed and Maskelyne, and says thes diff. prop. mot. would make Sidereal Astronomy wonderfully pro gressive.

M. Hell sent in 1759 (1758?) to Paris a catalogue of 1 mobile fixed stars.—Tycho Brahé. See La Lande, *Astronon.*, t. 3 p. 154, No. 2573 (*Astron. instaurat. Progymnast.* An. 1610, p. 233) M. Hell's letter to La Caille, August 20, 1758, on variable lati tude of 17 stars: received Mayer's writings through Mr Brawdler, a learned Englishman. (? Bowdler, S.M.D.)

P. 42, Mayer's original Memoir, *De centum stellarum fixarur comitibus eorumque insigni usu ad determinandum motum propriur fixarum.*

At p. 49 begins the author's dissertation: that the instru ment was a Bird's mural quadrant of 8 feet, fixed up in 1775, an so accurate that Bird obtained a reward of 500*l.*, enabling 3r magnitude stars to be seen at 10 A.M.; he argues, from Saturnia satellites, on the possibility of fixed-star ones.

Thus, *Comes Arcturus* followed in 1758 in $3\frac{3}{4}^s$ time; in 1777, in 6^s time: whereby (p. 65) all the comparisons of 500 or 1,000 years between instruments of extreme degrees of perfection are avoided.

Thus, Feb. 14, 1690, Flamsteed saw *Arcturus* 3^s after its Comes (7-mag.): and 26′ 30″ N. of Comes, in April 1736, at Greenwich, *Arcturus* preceded by $1\frac{1}{2}$ to $1\frac{3}{4}^s$, and north by 24′ 55″.

In May 1765, Maskelyne made difference 4^s time.

Mayer himself, in May 1777, found it 6 to $6\frac{1}{2}^s$.

P. 71 refers to Halley's announcement of proper motions, *Phil. Trans.*, No. 355, p. 736, for 1719; but La Lande, Tob. Mayer, &c., all trod in Halley's footsteps.

P. 78. Maskelyne in 1765–77 observed Comes to *Arcturus*, *α Scorpii*, *α Aquilæ*, *α Lyræ*, *α Cygni*, *η Gemini*, *ε Lyræ*, and twelve others, which Maskelyne calls *comes fixarum*.

P. 81. Kæstner, at Göttingen, has a 6-foot Bird's mural quadrant. Maskelyne's Letter, December 1, 1777, to Meyer concurs in his views; having on August 7, 1777, seen a 6-mag. star *α Hercul.* (Extract, Latin Letter.)

P. 90. Author adds *α Centaur.* *α Hydræ*, *Castor*, *γ Virgin.* *δ Serpens.* A *Ophiuchi*, *β Sagittar.* *o Capric.* *ζ Cancri* are all double stars (*Doppelsterne*); and *α Aries* (on December 23, 1876). *Cor Caroli* (2^s, 17″); *Regulus's* (10^s, 57″5); *δ Boötis* has (8^s, 18″). The double star *Castor* has one ($3\frac{1}{2}^s$, 4″); *ν Scorp.* (2^s, 33″); *β Scorp.* ($\frac{1}{2}^s$, $17\frac{1}{2}$″); near *ε Delphin.* (2^m, 2′) is a double star (apart $1^s{\cdot}8$, 3 to 5″); also *γ Delph.* (1^s, 11″.); *γ Androm.* (2^s, 4″5); *δ Orion.* (0^s, 50″): *β Lyræ* (2^s, 40″); *μ Cygni* (1^s, 2″5); a double star, with a comes (15^s, 93″); a double star near *γ Pers.* one near *α Androm.*; a tri-star near *x Pisc.*; *ι Cancri* is a double star, *ε Cancri*, *γ Cygni*, *β Lyræ*, *ζ Aquarii*, *π Pisc.*

P. 107. Finds in *two* years a change in light, apparent magnitude, and distance from greater member, to be *thought of* (*bedenklich*).

P. 108. Author asks if these starlets will fade away; and if this proper motion falls on small stars; if they move rectilinearly, or circularly round the greater star as their centre of gravity, whilst the greater and higher one courses round another sun or planet? or if, *vice versâ*, these starlets as a whole force the greater one to move round them? Quotes Le Seur and Jacquier on Newton. (*Princip.* tom. iii. *Genev.* fol. 670.)

P. 112. These double stars are either, 1) the smaller are opaque ones revolving round the larger; 2) dark spheres, round which mobile suns move; 3) or both luminous, revolving round a common point of rest: exemplified in solar system.

P. 116. Recounts *new stars* seen—his observations of Comet of 1769, August–September, at St. Petersburgh (Euler's period of 340 years). P. 123, quotes Lambert and Maupertuis (*Lettr. Progr. Science*, sect. 9, fol. 400. Central Sun).

P. 133. Proves Fixstar-satellites from changeable position of Comes to principal star; from observations upon Flamsteed's

time, especially (p. 179) *Arcturus*: Anno 1690 — 3ˢ, 26′ 30″ to 1778, + 5ˢ· 67, and 23′ 33″·7. P. 176–9, details Plate 1.

Then follows another refutation of Father Hell, with a detailed description of the Mannheim Bird's mural quadrant, and observations therewith.

He then (p. 206) explains the other diagrams of Plate 2; and this is followed by further anti-Hellite arguments, with extracts from La Lande,* Tycho Brahé, Halley, ending with Mayer's insisting on his method being new, *truly useful and excellent*; so that by the *differences* of motions of stars to each other, we will sooner acquire a notion of their movements, than by the old method of contemplating the absolute displacements from a common fixed point.

14 *Feb.* 1876.

Preliminary Note on Photographing the Least Refracted Portion of the Solar Spectrum.

By Capt. W. de W. Abney, R.E.

Within the last two years there have been many attempts made to photograph the least refrangible rays of the spectrum; and though stated to have been accomplished by the elder Draper on a daguerreotype plate in the early days of photography, yet there is reason to believe that this was effected by the reversing action of these rays on slightly exposed sensitive iodide of silver, and that really no direct photographic impression had been obtained till Dr. Vogel published an account of a method for effecting this object in 1874. More recently, Capt. Waterhouse, of the Bengal Staff Corps, has followed up Dr. Vogel's researches, and with a larger share of success than the originator. Both these gentlemen have had resort to aniline dyes of varying colour, using it with the preservative to the plate; and they state that the red end of the spectrum is most sensitive when a red dye (naphthaline) or rosine is employed, and propound generally that the rays that can be photographed are dependent on the colour of the dyes employed: that colour, and not the ingredient added to the sensitive silver salt, is the essential.

Lately I have had occasion to investigate the subject, and have met with such good results that I desire to communicate a preliminary Note to the Society. I have carefully repeated the previous experiments of Vogel and Waterhouse, and only attained partial success with them, though there was sufficient evidence to show that with the dyes the desired end would be attained. Looking more carefully into the chemistry of the

* *Vide* La Lande's *Bibliographia Astronomica*, p. 565. Refers to *Journal des Savans*, Feb. 1779.

question, however, it struck me that the same results might be obtained by other means than colour, and experiments were undertaken with a large series of gum resins and other oxidised hydrocarbons (added to ordinary collodion), some colourless and some not. With every gum resin was obtained a considerable extension of the photographic spectrum below the lines *b*, and at length I procured a resin forming with silver a perfectly white compound that seems to be capable of taking an image far below the line A. At present, I find that the longer the exposure given, the greater the length of the spectrum impressed, and I believe that, with patience, a very large part of the absorption-lines lying beyond that point may be registered, as I have obtained impressions which are constant in each plate exposed. The past winter has been of a most unsatisfactory nature for this kind of work, and it is only at long intervals that I have been enabled to catch the Sun for this purpose. I am earnestly looking forward to brighter sunshine, when I have not the least doubt that I shall obtain sharp fiduciary lines in the ultra-red. The addition of any colour to the preparations has been anything but beneficial, retarding the action greatly; and, from what is apparent, the virtue of the dyes used consists simply in the fact that they are hydrocarbons of some kind, probably combined with the faint traces of silver always left in the film of the sensitive plate.

Experiments with potassium bichromate have also been undertaken; and the result shows that (where partially insolated) the rays which usually have no effect on the sensitive compound are capable of continuing the action set up, as I pointed out in the year 1872. Iron and uranium have also yielded prolonged spectra.

The first experiments were carried out with a single prism of 60°, and a lens to the camera of 4-feet focus; the later experiments have been made with a direct-vision spectroscope of 9 prisms, being equivalent to about three single prisms, and with 4 prisms in battery. The same camera and object-glass have been employed.

Observations of Coggia's Comet. By G. H. With, Esq.

During July 1874 I made numerous observations of Coggia's Comet, with Newtonian telescopes furnished with silvered-glass specula, of aperture varying from $8\frac{1}{2}$ to $12\frac{1}{4}$ inches.

Notes of *three* of these observations may not prove uninteresting to the Fellows of the Society.

I also send copies of three sketches, made within a few hours of the time of each observation.

July 8, 1874, 10.30 P.M. I observed Coggia's Comet with an 8½-in. aperture Newtonian, furnished with a silvered-glass speculum, and power 125+. The nucleus was small and bright, with a fan-shaped jet of about 130°+ issuing from it. The envelope and coma were sharply defined at their outer edges; the central axis of the coma appeared almost black, with a fairly defined boundary.

I would direct special attention to the following fact:

A remarkable oscillatory motion of the fan-shaped jet, upon the nucleus as a centre, occurred at intervals of from 3 to 8 seconds+.

The fan seemed to "tilt over" from the preceding towards the following side, and then, for an instant, appeared sharply defined and fibrous in structure. Suddenly it became nebulous, all appearance of structure vanished, and the outline became merged in the surrounding matter.

At the moment of this change a pulsation was transmitted from the head through the coma, as though luminous vapour had been projected from the former into the latter.

These phenomena were observed many times during the evening, both by myself and a well-trained optical assistant.

They were not "glimpsed," but easily and most unmistakably seen.

July 11, 10.30 P.M. 12¼-in. speculum; powers 90 to 300+. A singular change had taken place in the shape of the jet proceeding from the nucleus. A spiral tendency appeared to have been developed in it; the fibrous structure was most distinct; also the width of the coma had increased. No oscillation as on the 8th was perceptible.

July 14, 1874, 10.30 P.M. (*see sketch*). 8½-in. speculum; powers 125 to 300+. On this occasion the nucleus was very bright and sharply defined.

The jet had resumed its fan-like shape, but was now enriched with a broad, well-defined border of condensed light. The envelope extended only a very small distance beyond the arc of the fan, which included, as on July 8, about 135°.

But above the primary envelope, and quite separate from it, were three faintly luminous, flocculent clouds of cometary matter symmetrically arranged and well defined in shape, though fading into blackness at the edges.

After this evening the observations presented no points of special interest. The oscillation of the jet was seen only on the 8th.

Hereford, 1875, *Nov.*

Extract from a Letter addressed to Mr. Ranyard on Drawings of Coggia's Comet. By R. S. Newall, Esq.

As you think the drawings of Coggia's Comet by Mrs. Newall, which were made at Ferndene on July 12 and 14, 1874, would be worth recording in the *Monthly Notices*, I beg to send them to you with the following remarks :—

I had observed the Comet on June 7 and 8. It was then a luminous mass with a distinct stellar nucleus. I had not another opportunity of seeing it till the night of Sunday, July 12, when we had a clear sky, but accompanied with the disadvantage of our usual, at that time of the year, highly illumined northern sky.

Fig. 1 is a very fair representation of what we saw. The nucleus was very bright, with a disk tolerably well defined. In front of the nucleus was a fan-shaped light, which seemed to arise from the overlapping, or duplication of the two tails, which streamed away behind for a length of about 15°, forming, as it were, two luminous veils, delicate, transparent, and flickering, leaving between them a black space, well defined up to the nucleus. The edges of these tails appeared to be brighter than the middle part, and crossing over the nucleus they formed the sides of the fan, the outside edges, also crossing over, formed the top of the fan and head of the comet. In front of this was another covering, semicircular and brightest in the preceding part, and in front of that was again another fainter envelope or cloud. The colour of the comet was greenish yellow. A small star was visible through the tail.

The next view we got of the Comet was on Tuesday, July 14, when a wonderful change had taken place. This is extremely well represented by fig. 2, which was made by Mrs. Newall, and was so exact that I did not touch it. Here the nucleus is still very distinct. The two streams of the tail have separated and become shorter, leaving a wider dark space between, while from the two corners of the fan proceed two anthenæ, which appear to be projections of the inner sides of the tails, and preceding these is still a luminous cloud.

On both nights the effect of motion was conveyed in a remarkable manner by the flickering of the tail.

Note on the Duplicate Structure of Coggia's Comet.

By A. C. Ranyard, Esq.

The drawings that were made of Coggia's Comet during the early part of July 1874 show that although there was but one small almost stellar nucleus there were two sets of parabolic

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WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Sir David Salomons, B.A. Nat. Sc., Broom Hill, Tunbridge Wells;

John Bagnold Smith, Esq., The Laurels, Chesterfield;

William Thomas Smedley, Esq., 20, Colmore Row, Birmingham; and

Thomas Watson, Esq., J.P., F.R.G.S., 15, York Place, Portman Square;

were balloted for and duly elected Fellows of the Society.

An Instrument for Determining Spherical Triangles by Mechanical Action. By F. C. Penrose, Esq.

Two planes formed of wood or any suitable material are hinged so as to revolve with respect to each other, through an angle of 180°, on a common axis.

One of these planes is bounded by a semicircle, the other by a segment rather exceeding a quadrant, but both to the same radius.

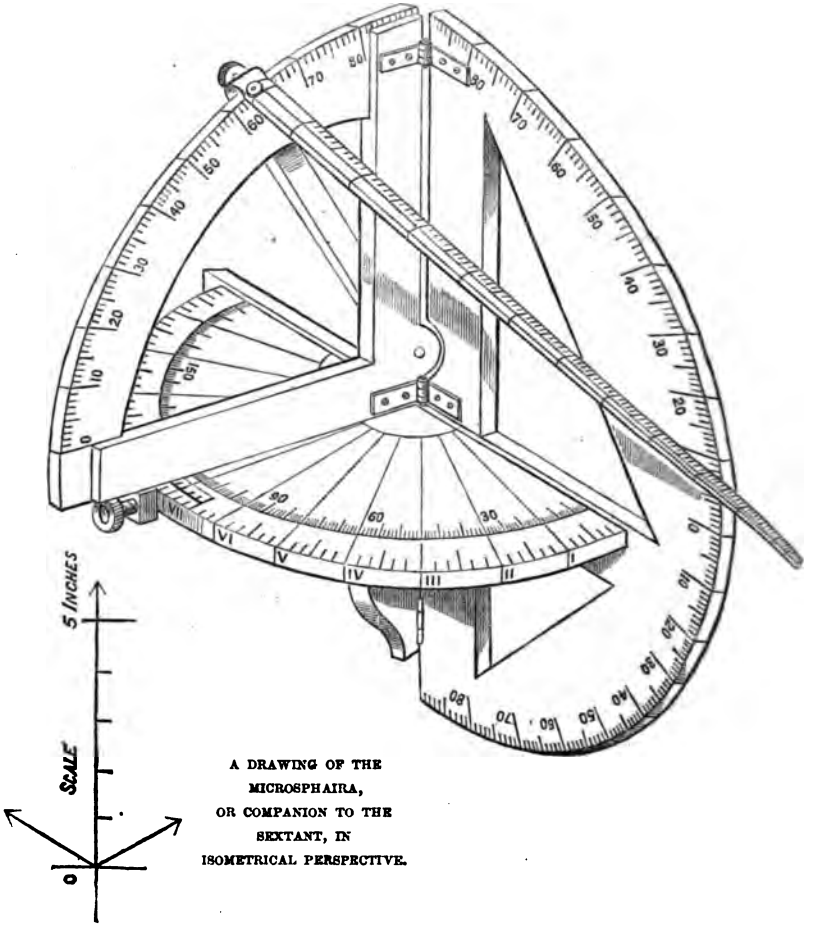
Below this last-mentioned plane, and at right angles to the axis upon which the two planes revolve, is another plane bounded by a semicircle, but cut to a smaller radius, about two-thirds of that of the former. This is hinged so as to fall down like the flap of a fold-up table, for the purpose of rendering the instrument more portable.

The three planes are graduated on their circular edges; the two former into degrees, the latter more particularly into divisions representing hours and minutes.

An arm or radius bar is centred so as to carry a point along the graduated edge of the quadrant, and from this point issues a

link, free at the other extremity, and graduated with a scale of chords measured from a circle of the larger radius mentioned.

This link, by means of an universal joint at the point first described, is enabled to be placed in any direction, and can thus be applied to any part of the graduated edge of the semicircle first mentioned, namely, that which is hinged upon the same axis as the quadrant. Clamps are placed upon the radius bar, and upon the extremity of the quadrant plane, so that they may be fixed in any position that may be desired.



A DRAWING OF THE MICROSPHAIRA, OR COMPANION TO THE SEXTANT, IN ISOMETRICAL PERSPECTIVE.

By means of these three graduated arcs and the free link, any ordinary problem in spherical trigonometry can be determined by mere inspection and without calculation: the most usual

cases in one operation, and others somewhat more complex in two.

For instance, if three sides are given and combined on the instrument, one of the angles will be shewn on the semicircular plane; or if an angle and two sides are given and combined upon the instrument, the third side can be read off upon the free link or upon the semicircle, according to the nature of the problem; but if two sides and an angle are given and an angle is required, or if two angles and a side are given, two operations would be necessary. They can be performed, however, with great rapidity.

The instrument can be used as a useful check to logarithmic computations; and as its accuracy is not inconsiderable [for instance, in a well-made instrument it would determine the hour-angle, or the azimuth from an altitude of the Sun, &c., taken near the prime vertical to about 20 seconds of time or 5′ of arc], it might sometimes stand in the place of logarithmic computations altogether, and be used as the companion to the sextant by navigators and travellers in unexplored regions; and especially so since by far the most accurate purpose to which it can be applied (so far as my experience of it enables me to speak) is in reducing the ordinary Lunar distance observation, by performing on the instrument the operation of "clearing the distance"—for the ratio between the effect of parallax on the measured distance and the parallax in altitude, can be found very readily and to a degree of accuracy not inferior to any other approximate method. The error, for instance, would scarcely ever exceed five seconds of arc; and a few printed tables can be affixed to the blank parts of the instrument to render it, for lunar measures, independent of all books, except the *Nautical Ephemeris*.

Radiant-Points of Shooting Stars. By William F. Denning, Esq., F.M.S.

(*Communicated by R. S. Greg, Esq., F.R.A.S., F.G.S.*)

The following Radiant-Points have been deduced from the observed paths of nearly 900 shooting stars, seen during the last four years at Bristol. The positions (which are chiefly those of the primary meteor-showers) have been ascertained by pencilling the courses on a Cary's 18-inch globe, and prolonging them backwards, the average places of convergence being selected as the approximate areas of radiation. The results were obtained independently of any previously published list; and a later reference to the valuable data of Professor Herschel, Mr. Greg,

Dr. Schmidt, Capt. Tupman, and others, tabulated in the annual reports of the Luminous Meteor Committee of the British Association, show that in many cases there is a close agreement.

No. 1876. Denning.	Dates of Observations.	Radiant-Point. R.A.	Dec. N.	Name or Position of Radiant.	No. in Greg's List, 1874.	Remarks.
		°	°			
1	1873 Jan. 2–3	234	48	North of α Boötis.	6	A marked shower.
2	1876 Mar. 12–17	184	54	ε Ursæ Majoris.	21	Also at *Cor Caroli*.
3	1874 April	223	45	Hercules.	48	3° N. of β.
4	1873–4 April	241	69	Draco.	57	Near ζ; same as 10?
5	1873–4 April	268	85	Polaris.	60	A marked shower.
6	1874 April	209	3 S.	Virgo.	62	12° E. of α.
7	1873–4 April 19-20	274	37 N.	Lyraids.	51	Mean of two showers well observed.
8	1873 April 19—May 1	221	20	Boötes.	?	9° E. of α; doubtful.
9	1874 April 20	242	25	Corona.	67	9° E. of α.
10	1873 April 21	283	59	Draconids.	64	Precise at ο *Draconis*.
11	1873 Apr. 21—May 1	173	64	Ursa Major.	?	Doubtful.
12	1873 April 21—May 1	189	60	ε Ursæ Majoris.	46	Connected with 2?
13	1873 June 25—July 8	164	57	Ursa Major.	76	Near β.
14	1873 July	267	49	Eridanus.	78	Near γ.
15	1875 July 7	344	27	β Pegasi.	96	Same as *Pegasids*?
16	1873 July 26—Aug. 11	2	27	α Andromedæ.	103	Identical with 17?
17	1873 Aug. 2–11	10	42	Andromeda.	98	Near the Nebula.
18	1871 Aug. 10	37½	58½	Perseids.	108	Central region well observed.
	1874 Aug. 10	44	58½			
19	1874 Oct. 17–18	34	18	Aries.	154	6° S.E. of α.
20	1874 Oct. 18–19	88	11	Orionids.	157	2° N. of υ.
21	1874 Oct. 19—Nov. 10	71	43	Auriga.	136	Near *Capella*.
22	1872 Nov. 6–10	64	20	Taurids.	156	Well observed.
23	1872 Nov. 27	29	46	γ Andromedæ.	172	A great shower.
24	1875 Dec. 19–23	277	73	χ Draconis.	?	Doubtful.
25	1872 Dec. 31	140	45	Ursa Major.	2	7° S. of θ.
26	1872 Dec. 31	164	20	δ Leonis.	?	Doubtful.
27	1872 Dec. 31	106	36	Geminids.	178	Near *Castor*.

Of the August shower in 1871, 260 meteors were seen in 8¾ hours on the 9th, 10th, and 11th. In 1874, 281 were counted

in 4 hours, and 252 of them were Perseids. Of the April shower in 1873 18 Lyraids were seen, and 14 in 1874. In regard to the minor displays, the radiant-points have been determined from a smaller number of meteors, but in cases (and they were found numerous) where the number were insufficient to indicate them, the observations were discarded.

Mr. Greg's List (1874), to which references are made in the table, is published in *British Association Report*, 1874.

Observed Courses of 71 Bright Shooting Stars, seen at Bristol from November 1872 to March 1876.

By William F. Denning, Esq., F.M.S.

(*Communicated by R. S. Greg, Esq., F.R.A.S., F.G.S.*)

The bright shooting stars, whose apparent paths are recorded in the following list, were seen either during occasional watches for them or casually. The table only includes those estimated to equal or excel 1st mag. stars, and does not comprise the total number of such meteors seen here within the interval mentioned, for during the fine showers of November 27, 1872, and August 10, 1874, the paths of many of them were not noted, attention being mainly directed to the aggregate numbers visible, to eye-estimations of the radiant-points, and to other details.

The times of apparition may be relied on as accurate to within a minute or so; but in some cases a meteor was observed by me when absent from home, and on such occasions a watch had to be consulted for the time, which, however, I afterwards verified, and hence there is little chance of error on this account.

The magnitudes given are those of *maximum* brilliancy, and the comparisons are with planets or 1st mag. stars.

The observed paths were projected on a celestial globe, and the R.A.'s and Declinations of beginning and ending, together with the length of path, read off, the latter element being less carefully noted than the two former, which give the more important one of *direction*.

I have affixed a column giving the probable "Radiant by stars," and in finding these positions referred, in many doubtful cases, to Mr. Greg's "General Comparative Table of Radiant Positions and Durations of Meteor Showers" (*B. A. Report*, 1874), which is continued and extended from a similar catalogue by the same author in the *Monthly Notices R. A. S.*, vol. xxxii., pp. 345–55.

The column of "Notes" indicates either the path of the meteor amongst the stars, the rate of motion, or the appearance of a train and its duration.

List of the Observed Courses of 71 Bright Shooting Stars, seen at Bristol during the Period from November 1872 to March 1876.

	Date.	Mean Time.	Mag.	Observed Path. From R.A.	From Dec. N.	To R.A.	To Dec. N.	Length of Path	Direction or Radiant by Stars.	Notes.
	1872.	h m		°	°	°	°	°		
1	Nov. 23	7 20	> ♀	18	44	131	63	60	γ Andromedæ.	2 secs.; long path.
2	25	8 5	1	150	63	165	61	7	α Aurigæ.	Between the Pointers.
3	27	5 50	♀	162	69	171	60	10	γ Andromedæ.	Fireball; slow; sparks.
4-7	,,	5 55	1	159	77	182	58	20	γ Andromedæ.	Average course of 4 bright meteors, seen in rapid succession, in a clear space in North.
8	28	5 45	1	55	74	73	27	22	α Persei.	↓ Fell vertically, leaving sparks.
9	Dec. 2	9 30	Sirius	154	78	268	76	22	Gemini?	Train for 2 secs.; across *Ursa Minor*.
10	26	7 58	> ♀	343	22	338	4 S.	26	β Pegasi.	Fireball; illuminated sky, like lightning.
11	31	12 27	1	164	15	162	3 N.	13	δ Leonis.	In *Leo*.
12	,,	12 42	Sirius	130	5 S.	140	25 S.	21	θ Geminorum.	1½ sec.; west of *Cor Hydræ*.
	1873.									
13	Apr. 19	9 28	1	295	46	316	51	14	α Lyræ.	Slow; through *Cygnus*.
14	20	9 28	1	292	55	360	72	32	α Lyræ.	Slow; train; long path.
15	,,	10 55	1	225	19	246	16	20	α Boötis.	Slow; just above β and γ *Serpentis*.
16	21	11 7	1	295	45	309	49	10	α Lyræ.	Train; began near δ *Cygni*.
17	30	9 25	1	218	14	233	13	14	α Boötis.	Train 1½ sec.; slow.
18	May 1	9 15	1	181	24	182	2	21	ε Ursæ.	Train 1 sec.; slow.

19	June 25	10 58	1	132	56	120	53	6	β Ursæ.	↘	Towards *Lynx*.
20	28	11 12	1	298	87	336	73	14	β Ursæ.	↗	Inclined upwards from *Polaris*.
21	July 20	9 26	1	124	62	106	52	19	Hercules.	↘	Towards *Lynx*.
22	28	11 32	♃	210	49	200	38	14	β Pegasi.	↓	*η Ursæ* to *Cor Caroli*.
23	,,	11 48	1	202	44	193	36	10	Draco?	Rapid; 2° E. of *Cor Caroli*.	
24	30	10 45	1	42	43	45	36	8	χ Persei.	Near *Algol*.	
25	Aug. 2	11 40	♃	43	54	62	56	12	β Pegasi.	↙	Began near *η Persei*.
26	7	9 33	2 × ♀	190	59	195	30	30	Polaris?	Train for 7 secs.; a fireball.	
27	9	10 15	♀	41	75	196	73	30	χ Persei.	←	Long path.
28	,,	10 29	1	37	45	50	42	10	ζ Cygni.	↙	Rapid; between α and β *Persei*.
29	,,	11 25	1	337	59	304	50	20	χ Persei.	↗	Inclined upwards.
30	,,	11 29	1	28	41	12	46	12	Pleiades,	↑	Shot upwards; train for 3 secs.
31	11	8 57	1	360	35	353	27	11	χ Persei.	→	Horizontally.
32	,,	9 11	1	11	40	21	29	13	δ Cephei.	↓	Vertical; slow.
33	Dec. 17	7 48	1	284	65	283	57	8	Draco?	Rapid.	
34	22	7 59	1	59	44	39	52	16	α Aurigæ.	Rapid; across α *Persei*.	
	1874.										
35	Jan. 6	10 20	1	...	...	...	...	...	...	↓	Slightly east of *Cor Hydræ*; almost vertical; near horizon; very slow; red; Radiant at *θ Gem.*; seen in bright moonlight.
36	Apr. 11	9 18	♃	243	47	278	50	24	β Boötis.	Very slow; near β and γ *Draconis*.	
37	19	10 11	1	218	13	216	4 S.	17	β Boötis.	Train; began at ζ *Boötis*.	
38	20	10 6	1	268	46	276	32	15	Draco?	Train; west of α *Lyræ*.	

No	Date.	Mean Time.	Mag.	Observed Path				Length of Path.	Direction or Radiant by Stars.	Notes.
				From		To				
				R.A.	Dec. N.	R.A.	Dec. N.			
	1874.	h		°	°	°	°	°		
39	April 20	11 48	1	280	26	286	13	15	α Lyræ.	Train; towards ε and ζ *Aquilæ*.
40	„	12 31	1	280	8	283	2 S.	11	α Lyræ.	Rapid; near horizon.
41	„	12 49	1	313	30	326	26	10	α Lyræ.	Rapid; across ζ *Cygni*.
42	Aug. 18	11 36	Sirius	24	36	68	44	33	α Andromedæ.	Slow; long path.
43	Sept. 1	8 49	?	...	...	...	...	...	...	Bright meteor; train; under η *Ursæ Majoris* for several minutes; an intense flash seen through clouds at the time stated.
44	6	8 40	♃	275	20	255	12 S.	37	δ Cygni.	Long path; train 1 sec.
45	Oct. 18	10 48	1	19	32	5	43	16	α Arietis.	Rapid; across the Nebula in *Andromeda*.
46	19	11 35	1	58	23	56	12	11	ν Orionis.	Rapid; train.
47	21	7 59	1	281	54	257	50	15	α Andromeda.	Very rapid; between β and γ *Draconis*.
48	„	11 6	Sirius	56	4	32	4 S.	25	ν Orionis.	Bright train; rapid.
49	22	7 34	1	142	56	129	58	10	?	Rapid; in *Ursa Major*, near θ.
50	31	8 23	1	169	77	137	60	19	Lyra.	Very slow.
51	Nov. 7	5 58	Sirius	313	70	335	57	16	Ursa Minor.	Very rapid; through *Cepheus*.
52	10	8 38	1	134	48	153	46	13	α Tauri.	Slow; between θ and λ *Ursæ*.
53	„	11 0	> ♀	43	30	7	4 S.	47	ν Orionis.	Very slow; long train, for 3 secs.; white.
54	„	11 11	1	20	6 S.	14	12 S.	9	ν Orionis.	A mere flash.
55	11	9 44	♀	31	6 S.	24	13 S.	9	α Tauri.	Slow; from *Mira* to ζ *Ceti*.

	1875.										
56	July	7	10 54	♃	37	64	25	47	15	β Ursæ.	Under *Cassiopeia*.
57		,,	12 2	♀	357	37	15	48	17	β Pegasi.	Train for 3 secs. } ↓² / ←¹
58		,,	,, ,,	♃	At right angle to preceding.					...	Left train for 1 sec. }
59	Aug.	1	9 25	♃	126	53	125	46	7	Polaris.	Rapid; train for 2 secs.
60		8	10 10	? = ♀	...	...	...	...	...	...	Near π *Pegasi*, from χ *Persei*; long bright train, visible behind clouds.
61		26	10 30	= ♀	41	63	64	63	10	β Pegasi.	↙ No train.
62	Dec.	12	6 36	♂	146	40	159	40	9	θ Geminorum.	Near horizon; very slow; red; seen in bright moonlight.
63		13	10 8	♃	142	52	185	52	26	θ Geminorum.	Very slow; seen in bright moonlight.
64		23	8 44	♃	93	44	93	16	28	Draco.	Slow; across μ *Geminorum*.
65		,,	9 27	1	38	60	10	63	13	α Aurigæ.	Rapid; across ε *Cassiopeiæ*.
	1876.										
66	Jan.	31	9 13	? ♀	64	12 S.	60	30 S.	18	α Tauri.	↓ Almost vertical; seen through clouds.
67	Feb.	2	8 31	♂	175	31	185	35	9	γ Leonis.	Slow; above *Coma Berenices*.
68		4	7 35	= ⅛th	74	4	50	1 S.	25	γ Leonis?	→ From γ *Orionis* to α *Ceti*.
69		29	6 35	1	358	52	357	59	7	?	Very slow; ↗ just below β *Cassiopeiæ*.
70	Mar.	1	6 46	♃	...	...	...	...	...	...	↘ Very bright; shot near ζ and ν *Ursæ Majoris* in E.N.E.; long path, from α *Persei* or ε *Ursæ Maj.*
71		17	8 15	1	145	10	135	7 S.	20	ε Ursæ.	↘ Train; to W. of *Cor Hydræ*.

Then

$$\begin{aligned} u &= \phi(x_1, x_2, \ldots . x^n) \\ &= \phi(s+h_1, s+h_2, \ldots . s+h_n) \\ &= \phi(s, s, s) \end{aligned}$$

$$+\left(h_1\frac{d}{dx_1}+h_2\frac{d}{dx_2}+\ldots . +h_n\frac{d}{dx_n}\right)\phi$$

$$+\left(h_1\frac{d}{dx_1}+h_2\frac{d}{dx_2}+\ldots . +h_n\frac{d}{dx_n}\right)^2\frac{\phi}{1.2}+\&c.$$

$$+\left(h_1\frac{d}{dx_1}+h_2\frac{d}{dx_2}+\ldots . +h_n\frac{d}{dx_n}\right)^r\frac{1}{\lfloor r}\phi(S+\theta h_1, S+\theta h_2, \ldots . S+\theta h_n)$$

$$= \phi(s, s, s)+(\omega_1 h_1+\omega_2 h_2+\ldots . +\omega_n h_n)\frac{1}{\omega_1}\frac{d\phi}{dx_1}$$

$$+\left(\frac{\omega_1 h_1+\omega_2 h_2+\ldots . +\omega_n h_n}{1.2}\right)^2\frac{1}{\omega_1^2}\frac{d^2\phi}{dx_1^2}+\&c.$$

Now let

$$s=\frac{\omega_1 x_1+\omega_2 x_2+\ldots . +\omega_n x_n}{\omega_1+\omega_2+\ldots . +\omega_n};$$

in this case we see from (A) that

$$\omega_1 h_1+\omega_2 h_2+\ldots . +\omega_n h_n = 0 \text{ identically,}$$

and therefore

$$u=\phi(s, s, s)=F\left(\frac{\omega_1 x_1+\omega_2 x_2+\ldots . +\omega_n x_n}{\omega_1+\omega_2+\ldots . +\omega_n}\right).$$

Let

$$\frac{\omega_1 x_1+\omega_2 x_2+\ldots . +\omega_n x_n}{\omega_1+\omega_2+\ldots . +\omega_n}=z;$$

then

$$u=F(z)=F(0)+zF'(0)+\frac{z^2}{1.2}F''(0)+\&c.+\frac{z^n}{\lfloor n}F^n(\theta z),$$

where

$$F(0),\ F'(0),\ F''(0),\ \&c.$$

are independent of z, and therefore of

$$\omega_1,\ \omega_2,\ \text{and}\ \omega_n.$$

But when

$$\omega_1=\omega_2=\omega_3=\ldots . =\omega_n,$$

$$u=F(z)=z$$

$$\therefore F(0)=0,\ F'(0)=1,\ F''(0)=0,\ \&c. \ldots . F=0;$$

or

$$u=z=\frac{\omega_1 x_1+\omega_2 x_2+\ldots . +\omega_n x_n}{\omega_1+\omega_2+\ldots . +\omega_n}.$$

No. in Catalogue.	Name of Star.
2563	Σ (719)
2589	ζ Canis Maj.
2601	Σ (723)
2850	Σ (780)
2932	Σ (805)
2949	25 Camelop.
3187	Σ (877)
3188	Σ (878)
3209	Σ (884)
3215	Σ (888)
3542	Σ (959)
3556	Σ (964)
3642	Σ (982)
3665	Σ (989)
3676	1 Ursæ Maj.
3728	Σ (1006)
3770	Σ (1015)
3827	Σ (1031)
3842	Σ (1036)
3883	Σ (1051)
3972	κ Ursæ Maj.
4007	Σ (1080)
4070	Σ 1328
4149	Σ (1116)
4163	α Hydræ
4180	θ Ursæ Maj.
4260	Σ (1147)
4447	λ Ursæ Maj.
4455	Σ (1189)
4479	μ Ursæ Maj.
4489	Σ (1200)
4758	β Ursæ Maj.
4768	α Ursæ Maj.
4789	Σ (1277)
4838	Σ (1290)
4877	Σ (1303)
4930	λ Draconis
4941	Σ (1319)
4946	Σ (1321)
4982	Σ (1332)
5044	χ Ursæ Maj.
5066	β Leonis.
5074	β Virginis
5095	γ Ursæ Maj.
5146	Σ (1592)
5233	δ Ursæ Maj.
5262	Σ (1409)
5340	κ Draconis
5398	Σ (1460) C.G.
5436	ε Ursæ Maj.
5591	Spica
5653	Σ (1537)
5749	η Ursæ Maj.
5860	α Draconis
5919	Arcturus
5992	θ Boötis
6025	γ Boötis
6126	α^1 Libræ
6194	β Ursæ Min.
6215	110 Virginis
6394	γ Ursæ Min.
6431	α Coronæ
6555	ζ Ursæ Min.
6601	θ Draconis
6608	Σ (1782)
6696	Σ (1814)
6748	Σ (1836)
6765	σ Herculis
6877	Σ (1884)
6887	ε Herculis
6919	Σ (1901)
6925	Σ (1903)
6939	ε Ursæ Min.
6991	Σ (1927)
7004	Σ (1932)
7068	α Ophiuchi
7092	Σ (1968)
7100	ι Herculis

the planet, to displace this idea of extreme difficulty from its long-established possession, and to show that these bodies, minute as they are, may be within the reach of the optical means, not only of our principal Observatories, but of a large porportion of amateurs. This fact appears to have been sufficiently established by Mr. Isaac William Ward, of Belfast, an accurate and persevering observer of considerable experience, whose success in the detection of many very minute *comites* vouches at once for the keenness of his vision and the excellence of his object-glass, which is one of Wray's, with an aperture of 4·3 inches. And I beg permission of the Society to lay before them the evidence which Mr. Ward has placed at my disposal, and which he has drawn up in a tabular form. The first observation, as he has remarked, is of course not connected with any satellite. The rest were mere glimpses, as may be supposed, obtained by most intense gazing, and with averted vision only.

The value and interest of these observations arise from the circumstance that in every instance the estimations were made quite independently, without previous reference to any Ephemeris; in fact, with regard to those in February and March, Mr. Ward had not at the time any tables in his possession. There is, of course, a possibility that the presence of very minute stars may have been a source of illusion, as it undoubtedly was with regard to other supposed satellites in the case of Sir W. Herschel; but considering the number of coincidences, the fair degree of approximation, the similarity of aspect in each instance, and the motion of the planet, it may perhaps be conceded that the balance of probability inclines strongly in Mr. Ward's favour.

I may be allowed to add, that, stimulated by Mr. Ward's information, and encouraged by the opinion of another experienced observer, I turned my beautiful 9·38-inch silvered glass "With" speculum to *Uranus* on the night of March 24, one of the very few favourable ones during the present season. With considerable difficulty, but without adopting indirect vision, I had occasional glimpses with a power of 212 of a very minute point in the *n f* quadrant, which, though of the most evanescent character, always when visible occupied the same position: and this was entirely confirmed by a power of 450. The next morning I found from the Ephemeris of Mr. Marth, to whom my especial thanks, and not mine alone, are due, that my very rough guess of a position-angle of about 30°, obtained merely from the motion of the planet or swinging the tube, might have either indicated *Titania* at 44° or *Oberon* at 23°. I noted the distance less carefully, and, from recollection only, supposed it might have been about 30″. *Titania* was then 24″, *Oberon* 41″. If I saw either, it was probably the former, as *Oberon* would have been less likely to be noticed near the edge of the very contracted fields I employed. Such an observation, standing singly, is of course worthless, and I have had no opportunity of repeating it; it is only in connexion with those of Mr. Ward that I could venture to mention it at all.

Observations of the Two Outer Satellites of Uranus, with 4·3-in. Refractor (Wray), 240 power, at Belfast, by Isaac Wm. Ward.

Lat. 54° 36′ N.
Long. 5° 56° W. from Greenwich.

Date. 1876.	Hour. ±	Titania. Position. Ephemeris.* ° ±	Titania. Position. Observed. ° ±	Titania. Distance. Ephemeris. ″ ±	Titania. Distance. Observed. ″ ±	Oberon. Position. Ephemeris. ° ±	Oberon. Position. Observation. ° ±	Oberon. Distance. Ephemeris. ″ ±	Oberon. Distance. Observation. ″ ±	
Jan. 15	13 hours	...	...	...	...	...	...	...	...	An elongation of Planet's limb, in direction of P 25°, like an occultation of a star.
20	13 „	...	...	...	...	330	330	29	30–40	
21	13 „	167	120	28	35	...	...	...	...	
26	13 „	320	330	20	25	167	170	38	35	
Feb. 1	12 „	34	30	27	25–30	359	360	44	50?	A faint point at ± P 260° and 25–30″ D.
3	11½ „	350	360	29	50?	...	...	...	...	A point at ± P 70° and 25″ ± D.
19	12 „	19	20	33	30	209	250?	39	25?	A faint point at ± P 120° and 25′ ± D.
23	12 „	207	200	30	30	...	...	...	...	
Mar. 1	11 „	312	...	...	...	306	310	24	30	
16	10 „	24	70?	32	25?	233	170?	29	30	
17	10 „	2	10	32	25	208	200	39	40	
21	10 „	186	200	34	35	129	140	26	25	

* In the *Astronomical Register*.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Sun-Spot Drawings of the Rev. Frederick Howlett and Hofrath Schwabe.

The Rev. Frederick Howlett has presented to the Society five oblong quarto volumes of Sun-spot Drawings, made by him in the course of the last seventeen years. In the first four volumes the whole of the Sun's disk is given on a scale of about three and a quarter inches to the Sun's diameter; the places of the spots, and the outlines of the groups and penumbræ, were laid down while the image of the Sun was thrown upon the paper by means of a three-inch refracting telescope by Dollond. Enlarged drawings of the more remarkable spots are also given. In the later volumes the drawings are made upon tracing paper, which is reversed in the book, so that they appear as if seen with an ordinary erecting eye-piece. The position of the north point is not marked upon the drawings, but as the hour and minute corresponding to the time of observation is in all cases given, the orientation of the Sun's disk may be approximately determined by calculation, the highest part of the drawing on the page being assumed to coincide, in the case of the earlier sketches with the part of the Sun's disk nearest to the horizon, and in the case of the later drawings with the part of the solar disk highest above the horizon.

In compiling the list of Sun-spot manuscripts, given in the March number of the *Monthly Notices*, the manuscript Observations of Hofrath Schwabe were by accident omitted. In 1864 Messrs. De La Rue and Balfour Stewart wrote to Hofrath Schwabe to request that he would allow his original manuscripts to be sent to England. In answer to their letter, the following communication was received:

"Gentlemen,—The request contained in your letter, although in the highest degree honourable and complimentary to me, and although it gives me an opportunity to show the Royal Astronomical Society my gratitude for the Royal Medal granted to me, has still cost me some struggle before complying with it, for it is not easy to part with what has given me very often much pleasure and enjoyment as a compensation for the labour devoted to the work.

"But in complying with your desire I do so on one condition, viz. that you would grant me permission to obtain the Observations back again at any time that I should be desirous of looking into them during the short time of life still left to me. I do not think that I shall have an occasion to avail myself of the permission asked for; but permit me kindly to believe that it is in my power to do so. After my death you may consider the whole of the Observations as the property of the Royal Astronomical Society.

"Please to write me if you are willing to agree to the above desire, and I shall then immediately send you my astronomical diaries, &c., from 1825 to the end of 1864.

"I remain, gentlemen, yours very faithfully,

"S. H. SCHWABE."

On receipt of this letter Mr. Loewy was despatched to Dessau by the Directors of the Kew Observatory, and Hofrath Schwabe delivered into his hands thirty-nine volumes, which have remained at Kew until the present time, but which are held by the Observatory as the property of the Royal Astronomical Society.

The following description of the manuscripts has been given by Mr. Whipple:—

1825. Small quarto; about 60 pages; commencing Sept. 30; principally occupied with detailed observations and drawings of the Lunar Surface. The first Sun-spot observation occurs on Oct. 30. Occasional details and positions given to end of year. Stitched; paper cover.

1826. Small quarto; about 400 pages. Contents similar to preceding vol. Some of the drawings very elaborate. In addition, there are several observations of *Saturn*, and a Table of Contents. Stitched; paper cover.

1827. Small quarto; about 400 pages. Contents similar to preceding vols. Has several drawings of *Jupiter* and one of *Venus*. Table of Contents. Half-bound; leather back.

1828–29. Large quarto; about 400 pages. Drawings and details of Sun-spots very numerous. A few drawings of other objects. Bound in brown holland.

1830. Large quarto; about 200 pages. Contents similar to preceding. Contains a series of well-executed drawings of *Mars*. Brown holland binding.

1831. Small quarto; about 300 pages. Sun-spot drawings, principally confined to indications of position. A number of drawings of *Jupiter*; scarcely any of lunar objects. Half-bound; leather back.

1832. Large quarto; about 200 pages. Very similar to last. Bound in brown holland.

1833–4–5. Three large quarto vols., each containing about 200 pages. Contents chiefly Sun-spot positions. Vol. for 1835 contains numerous drawings of Halley's Comet. Brown holland binding.

1836-7-8. Large quarto; about 350 pages. Contains drawings of Sun-spot positions, one observation of *Mars*, and a series of drawings of Encke's Comet. Brown holland binding.

1839-40. One vol.; foolscap; about 300 pages. Principally Sun-spot positions. Holland binding.

1841-51. Eleven vols.; large quarto; each averaging 250 pages. Contents similar to preceding. Drawings of other objects than Sun-spots are very few. Vol. for 1843 contains summary of Sun-spot groups observed from 1825 to the end of 1843. Holland binding.

Note.—A remarkably fine Sun-spot is delineated for Sept. 20, 1848. From 1846, at end of each year, there is a detailed summary of the Sun-spot observations made during the year.

1852-62. Eleven vols.; large quarto; each averaging 200 pages. Similar in character to preceding volumes. That for 1855, on the 25th of Sept., contains a nicely-finished drawing of *Jupiter* in colours. Brown holland binding.

1863-4-5. Three vols.; large quarto; about 100 pages each; containing observations of the usual character. Bound in brown holland.

1866-67. Unbound; stitched paper; about 100 pages each. They do not possess the Annual Summary of Sun Observations, which was discontinued in 1865.

On Lohrmann's and Schmidt's Lunar Maps, and Note on a New Red Star. By John Birmingham, Esq.

(*From a Letter to E. Dunkin, Esq., Secretary.*)

Perhaps you would be kind enough to inform the Society at the next meeting that Lohrmann's complete Map, of which four sections have been hitherto published, has been lately engraved by Herr J. A. Barth, of Leipzig, under the supervision of Dr. Schmidt, Director of the Athens Observatory, who has contributed a descriptive letter-press. The map is three feet in diameter.

Dr. Schmidt's own great Lunar Map of six French feet diameter will be soon issued from the *atelier* of the Prussian staff; the Prussian Government having, with great credit to itself, purchased it. It is the result of thirty-four years' labour, containing about 34,000 craters, and an equal number of hills, besides over 350 rills and other objects, and it must be considered a work of unsurpassed scientific capability and perseverance.

I beg you will also inform the Society that I have lately observed a red star of remarkable depth of colour in the approximate position of R.A. = $18^h\ 28^m$; Decl. = $+\ 36°\ 54'$; 8·3 magnitude. It does not appear as a red star in any Catalogue that I know of.

Millbrook, Tuam,
1876, *May* 10.

accurate and comparatively inexpensive. It is indeed plain that, when once the outfit, by no means a costly one, has been supplied and the staff trained, there the special expense of work of this kind practically ends. Any cruiser or surveying ship can carry on the measurements without prejudice to its routine services; and experience thus far has shown in the most gratifying manner that both foreign authorities and officials of telegraph companies are always ready to extend courtesy and gratuitous help to scientific work of the kind.

I proceed now to sketch the *modus operandi*, illustrating it by taking two stations, say Barbados and Trinidad, at both of which places observatory sites have been chosen by Commander Green, he himself on this occasion operating at Barbados, while his assistant, Professor Rock, is at Trinidad. The huts and instrumental outfits at both stations are exactly alike, with one exception only—the huts are of different colours. The instrumental outfit at each consists of a transit instrument adapted for use also as a zenith-telescope, a break-circuit sidereal chronometer, a small chronograph driven by a weight, keys for speaking and signalling, a Thomson's "mirror galvanometer," batteries, telegraphic fittings, lamps, &c. The transit pier is of brick, faced with cement, and is square in shape, its top surface consisting of four tiles, each about a foot square, laid and levelled with extreme care. The meridian line is laid out with a compass in the usual way. The instrument is of the large portable kind, and has a universal movement, with a horizontal circle of about ten inches diameter, a form of construction which admits of its being very readily used, if required, for observations in the prime vertical. Its base consists of a tripod-stand, with footscrews, carrying a cylinder which receives the vertical axis, and to which the horizontal circle is fixed. From the head of this axis, two opposite arms extend horizontally, and are then bent up to form the supports for the telescope axis, which are about eighteen inches apart. The telescope is of the axis-view construction, and its object-glass is of about $2\frac{3}{4}$ inches clear aperture, and 27 inches focal length. The finding-circle is on the eye-end of the axis. The transit threads are eleven in number, viz.: a central group of five, with a group of three a little on either side of it, all of them being fixed. There are the usual central horizontal threads, and others arranged obliquely for zenith-telescope work; there is also a movable zenith distance micrometer wire.

This instrument, like most of its class, is subject to one rather serious source of error, through flexure of its transverse axis, the error produced varying, just as a level error, with the cosine of the zenith distance of the body observed. The extent of this defect was however carefully investigated in the United States before the expedition set out, and a coefficient of flexure was found for each instrument, from scrupulously careful observations at every 5° of zenith distance.

The hut, about 9 feet square, has its door in the middle of the

north side. On a table in the north-east corner is the break-circuit chronometer, in connection with a small barrel chronograph driven by a weight and wheel-work, which stands on a little table in the north-west corner. The performance of this chronograph is very satisfactory. A pencil attached to the electro-magnet describes an endless spiral on the chronograph sheet, making however a little nick or notch whenever it is momentarily moved aside by the action of the electro-magnet, either through the operation of the chronometer at each second or from the observer's tap with his break-circuit key. The numeration of seconds is marked in the usual way, by omitting the record of one second in each minute. On the same table with the chronometer is the speaking instrument,* connected with the head telegraph office; and used also in the time-signalling; and above it is the Thomson's galvanometer, its mirror reflecting a small rectangular patch of light from an orifice in a screened lamp on to a sheet of white paper fastened to the wall of the hut above the table. The break-circuit key used in tapping transits, &c., for chronographic register, with its attached wires, is movable. During transit observations, it can be held in the hand, or laid on the pier: Commander Green preferred the former.

I was with Commander Green on his first night's work at this place. There was nothing new in his method of adjusting the instrument to the meridian. It was done, however, with most unusual speed, partly owing, no doubt, to an admirable printed form of "Programme," in which the observer enters beforehand the name, position, magnitude, setting, &c. of every star he intends to use, and is thus able to proceed from star to star with the least possible loss of time. Twelve minutes' work enabled Commander Green to get his instrument very approximately into position.

For the time determination, clock stars of north declination, and therefore near the zenith, of this place, were chiefly used. The level (a most excellent one) was on this account read very frequently; but, as the construction of the instrument allows of the level being kept on the pivots without being disturbed except for reversal, this gave little trouble. Some clock stars a little N. of the zenith, and some S. of it, were observed. The usual routine is to observe 3 or 4 circumpolar, and 8 or 10 clock stars nightly, about half of each before and after time-signals, and half in each position of the axis, reversal being made on a circumpolar star once in the evening. A test value of the collimation error of the middle wire is obtained from this reversal; but in the reduction, both the collimation and azimuth errors are treated as unknown in the series of equations for clock error, and are rigorously solved for by the method of least squares.

In time-signalling, the process is as follows:—Let B and T be the operators at Barbados and Trinidad respectively. About

* This is a double "Key" for sending positive and negative signals.

sunset, weather prospects are telegraphed between the two, and these being satisfactory, arrangements are made for signalling at about 9^h or 10^h. At the appointed time, B calls T, and finding him ready, seats himself at the chronometer, and sends the following signals:—

A warning rattle, beginning at 50 secs., and lasting for 5 secs.

Single signals, at 0^s 5^s 10^s 15^s 20^s . . . . and so on to 60 secs.

A rattle at 5 secs., lasting for 5 secs.

T, having darkened his hut sufficiently, just acknowledges the warning rattle: then, taking the movable break-circuit key, which is in circuit with the chronograph, into his hand, he watches for the first movement of the patch of light which is reflected on the white paper from the Thomson's galvanometer. Each five-seconds signal sent by B is recorded on the chronograph when received by T, who strikes his key every time directly the light-spot is seen to move. The single signals over, T acknowledges B's last rattle.

B now promptly telegraphs the hour and minute of his first single signal, and T acknowledges it.

At the next 50 secs., B begins again with a rattle, and exactly repeats with T the above operation; and this is done five times in all.

Then T takes the sender's, and B the receiver's place, in precisely the same manner, for five minutes. This ends the night's signalling.

Three such nights of comparisons are considered to be sufficient for a pair of stations.

The time occupied by the passage of signals from the sending-point through the cable (up to the instant of visible movement of the light-spot), and also through the chronograph circuit at the receiving station, may be considered as eliminated by sending the signals both ways. But, as the observers do not change places at any pair of stations, there will remain as constant sources of error, affecting measurements of meridian distances by this method, the personal equations of the observers, (1) in observing transits; (2) in tapping the key at the sending station in coincidence with the chronometer beats; (3) in tapping the key at the receiving station simultaneously with the first visible movement of the beam of light. These sources of error have been carefully gone into amongst the observers engaged in the work.

For determining the absolute personal equations in observing transits, a "personal-equation machine" was used. Two or three kinds of this apparatus have, I believe, been brought out in the United States. An account of one, devised by himself, is given by Professor W. Harkness, in the Appendix to the *Washington Observations*, 1870. The principle of it is, that a series of five artificial stars attached to a chronograph cylinder is made to transit a single wire in a fixed telescope, at an apparent angular velocity corresponding with that of an equatoreal star crossing the wires of the transit instrument in the meridian, and at cor-

responding intervals of time. The observer records chronographically the transit of each star over the wire, and the difference between his record of any transit and the previously-made mark on the chronograph sheet which corresponds with actual bisection of the star gives a measure of his absolute personal equation. Another kind of the same instrument was mentioned by Commander Green. I have not seen a written account of it, but I gather from his description that, in this case, a system of wires is made to move past a single star, instead of a set of stars past a single wire. As each wire passes, not exactly the star, but a point at a certain small known interval from it, it makes an automatic register on the chronograph. The observer also registers the transit on the same chronograph; and a comparison between the two registers, making due allowance for the small interval abovenamed (which is contrived purposely that there may be no confusion), gives a measure of the personal equation. The size of the artificial star can be varied to represent stars of different magnitudes.

The two kinds of personal equations in time signalling are found in combination, I believe thus: Two break-circuit chronometers, C_1 and C_2, are both made to register their beats on the same chronograph cylinder, for some little time, so as to give an absolute comparison between them, and the rate of gain of one upon the other. The observers now proceed to compare C_1 and C_2 in a similar manner to that described for time signalling. B goes to C_1 and sends signals by ear, which T receives by the Thomson's galvanometer and registers on the chronograph, which remains connected with C_2. The difference between the comparison of C_1 and C_2 thus obtained, and their absolute comparison (allowing for rate), may evidently be taken as the sum of B's personal equation in sending, and T's in receiving. B and T now change places, and repeat the above operations, in order to find the sum of T's personal equation in sending and B's in receiving. This is all that is needed, as the double operation gives the corrections to be applied in the case of either observer sending while the other receives.

In determinations of latitude with the transit instrument used as a zenith-telescope, from 6 to 12 pairs of stars observed on the meridian on three nights, making from 18 to 36 determinations in all, are considered to give a result sufficiently good, probably within about $0''{\cdot}5$ of the truth.

From the account I have here given of Commander Green's operations in these seas, it will, I think, be seen that they are simple and thoroughly practical, and executed with an accuracy which leaves nothing to be desired, being in fact surrounded with all the precautions and safeguards which should be looked for in work of a precise order. I believe that this is the first naval expedition as yet made for establishing secondary meridians by telegraphic time comparisons, and for exact determinations of latitude. The region which has been chosen is in every respect

well suited for a first experiment, the facilities being great and the field large, while many uncertainties in the longitudes, especially on the south shore of the Caribbean Sea, where they amount to some five or six miles, need to be cleared up. In other parts of the world, however, the uncertainties are a good deal greater. It is not too much to hope that other nations will promptly follow the lead taken by the American hydrographers, and that especially our own Hydrographic Department will add this branch of work to the admirable maritime surveys in which it is justly pre-eminent. The vast and constantly spreading network of telegraphic cables and land lines will afford work for many years to come; and each extension of measurements of the class I have described will add accuracy to geographical knowledge and marine cartography.

Barbados, West Indies,
1876, March 20.

On the Relative Power of Achromatic and Reflecting Telescopes.

By T. R. Robinson, D.D., F.R.S., &c.

In an article which appeared in *Les Mondes*, Jan. 20, 1876, by M. Radau, on large Telescopes, he remarks, after noticing the comparison of the relative illuminating power of Achromatics and Reflectors, which I made in the description of the Great Melbourne Telescope (*Phil. Trans.* 1869), "the theoretic proportion established by Mr. Robinson between equivalent apertures of a Reflector and Refractor is not however conformable to experience, which is entirely in favour of the Refractor."

Even were it true that an Achromatic shows objects better than an equivalent Reflector, it would not contradict my theory, which merely refers to light. The theory is, in brief, that a speculum collects in its focus a quantity of light proportional to its area, and a constant depending on the reflective power of its material; the Achromatic a quantity depending on its area, and a co-efficient which contains a negative exponential function of the aperture, and of course decreases more rapidly than the area increases. Therefore, though for small apertures the light of the Achromatic exceeds that of an equal speculum, yet as the aperture increases, the disparity decreases until at a size determined by the reflective power of the speculum and the refractive indices and absorptive power of the glasses, their lights become equal; and above that the Reflector predominates. Since, therefore, both the difficulty and cost of construction increase far more rapidly with aperture in the Achromatic than in the Reflector, it is evident that as far as light is concerned, the ultimate practical limit of telescopic research can only be obtained by the latter.

Having premised so much, I proceed to consider (1) what

reasons can exist for the superiority that is ascribed to the Achromatic, and (2) whether they *do* exist.

If one of two equiluminous telescopes shows a faint object better than the other, this can only arise from the first condensing its light into a smaller image. In this respect the Achromatic presents greater difficulties than its rival: it has two aberrations to be corrected, chromatic and spherical, of which the first is never completely destroyed,* and the second requires the careful figuring and centering of four surfaces; any defect of homogeneity in its glasses disturbs the image; defective annealing, from which scarcely any large lenses are free, tends to produce diffusion, and the same mischief may arise from strain caused by pressure on its supports.

On the other hand, a speculum has only one surface to be figured, and with the present improved processes of polishing, *that can be done with remarkable precision.* But it is very sensitive to irregular pressure. This has been greatly remedied by the systems of supporting levers invented by Grubb and Lassell, which may probably be still further improved; and I believe that by a better mechanical disposition of the material, its strength may be greatly increased. The only point in which it is decidedly inferior to the object-glass is the occurrence of convection currents when the speculum and the air differ much in temperature. Even this is greatly obviated by making the tube of lattice-work, and it would not be difficult to devise mechanical means to reduce it still further. It is also to be noticed that there are some grounds for believing that large Achromatics have their aberration correction disturbed by considerable changes of temperature.

On the whole, therefore, it may be expected that a good instrument of either class shall perform equally if equal in light; and it is certain that superior definition will compensate only to a very limited extent for deficiency of light.

But secondly, what evidence have we that "Experience is entirely in favour of the Refractor?" None that will bear examination.

1. We are told that W. Struve thought the Dorpat telescope of 9·6-inches aperture might be compared to Herschel's 20-feet of 18-inches aperture. This rested mainly on the fact, that he discovered with it the 5th star in the Trapezium of *Orion*, which was not seen by J. Herschel in his careful examination of the Great Nebula. The obvious explanation of this is, that Herschel was attending to the Nebula and nothing else. But, in fact, his telescope showed not only the 5th, but also the 6th star which was in the Dorpat. Lassell saw both in a 9-inch Newtonian; and I have myself seen the 5th with a zone of the Armagh Cassegrain,

* It is doubtful whether the Harcourt glass, with which Mr. Stokes has recently formed an object-glass free from secondary spectrum, can be made on a large scale.

the area of which was only 0·78 that of the Dorpat. This object is, therefore, far within the range of any of these telescopes.

2. Otto Struve *thought* that the Pulkowa Achromatic of 15-inches was equal to Lassell's 24-inch Newtonian (not his 4-feet, as supposed by M. Radau): nothing definite can be built on this. It seems only to have shown three satellites of *Uranus*, while the other (Lassell's) showed four.

3. We are told that M. D'Arrest's Achromatic of 11-inches aperture "is very superior to Herschel's 20-feet, and almost equal to the great telescope of Lord Rosse."

D'Arrest himself, though very enthusiastic about his instrument, makes no such pretensions. In his *Instrumentum Magnum* he merely says, that "he could reach with his telescope all the Herschel Nebulæ without any exception," and in the preface to his great Catalogue that "it is in no wise inferior, non ullo nomine postponendum, to the Herschel telescopes on which this part of science had been built." But seeing all these Nebulæ does not prove that the telescope was equal in power, unless all the other conditions were identical. (1.) It is far easier to see an object the existence, place, and form of which are known than to discover one that is unknown; examples of this are familiar to every one who has used a telescope. (2.) He had the great advantage of a steady Equatoreal moved by clockwork; this gives a power of minute examination, the value of which can be appreciated only by persons who have worked with telescopes mounted like those of Herschel and Rosse. (3.) Much depends on the observer's power of vision; if M. D'Arrest were as sharpsighted as, for instance, my friend the late Mr. Dawes, this would compensate for considerable deficiency of optical power. No satisfactory comparison can be made from the descriptions in catalogues; they are always incomplete. No description of a tolerably complex nebula would enable a man who had not seen it to make a drawing at all like it. D'Arrest, in his *Instrumentum Magnum* has given some figures, which show superiority to those of Herschel where they differ; and where they are also given in Lord Rosse's papers (*Phil. Trans.* 1844, 1850, 1864), Herschel is on the whole nearer to these last than D'Arrest. As to the notion that the Danish telescope "is almost equal to Lord Rosse's great one," we have only to compare D'Arrest's fig. 4, of 1 M, with Rosse's fig. 81, *Phil. Trans.* 1844, taken with the *three-feet*, to be convinced that even this lesser telescope is enormously superior to the other.

Let it also be remembered that while two of the satellites of *Uranus* were *observed* repeatedly with the 20-feet, there is no evidence that any of them were ever *seen* in an 11-inch Achromatic.

All these statements of the superior power of Achromatics are so little supported by accurate data, that it may seem a waste of time to confute them, but such baseless assertions "darken knowledge" and if accepted, impede progress. I repeat my belief that it is only by large Reflectors that we shall reach the utmost depths

of celestial exploration in stellar spectroscopy, and the study of the remoter planets and Nebulæ; and, instead of unwisely depreciating this power, it is a wiser course to consider how their real defects may be remedied.

Of these the most serious is the liability of speculæ to tarnish, and the consequent necessity and risk of frequent repolishing. Has science no means of preventing the tarnish, which is an oxidation of the surface probably caused by the presence of moisture?

Lord Rosse and I separately tried to guard against this by connecting with the speculum box (when the instrument was not in use) a vessel containing quicklime; but I have some reason to think that as it became "slacked" it evolved something that acted on the metal.

Would it be protected by keeping it in a state of negative electric tension? Sir John Herschel told me that when his father sorrowfully showed him a 20-feet speculum, the finest he had ever made, but then become black, he delighted the old man by restoring completely its polish, having placed it in a solution of salt in contact with a piece of zinc; and afterwards it did good work.

The operation of polishing even a 6-feet, is neither so difficult or uncertain as many persons suppose. If, when the right mode of making the polisher, and the proper action of the machine, are once ascertained, they be exactly formulated, *and that formula be always carefully followed*, I venture to assert that failure will be very rare.

The late Lord Rosse—while, with that caution which was so remarkable a feature of his character (*Phil. Trans.* 1864), he rather overstates the uncertainty in the process—also says, that in every such instance something which experience had shown to be important had been forgotten or neglected. In the case of the 6-feet, the difficulty was much increased by the impossibility of testing the figure of the speculum while the polishing was proceeding: it had to be removed to the telescope half a mile distant for trial, which owing to unfavourable weather sometimes could not be made for many days; and this suspension was unfavourable, for the operation should be continuous. This, and the trouble of moving so great a mass, sometimes made him work with surfaces of second-rate quality. Towards the close of his life he contrived the means of setting the speculum vertical on the machine, so that in a few minutes it could be tested on a watch-dial. The 3-feet was from the beginning tested on the machine, and success with it was almost certain. But even with the old method I have seen results for the 6-feet that gave marvellous definition, and none that in favourable atmospheric circumstances were not capable of doing work beyond the power of any telescope which then existed. The time of actually polishing it need not exceed 6 hours; and though he never used the same polisher twice (the making of which is rather tedious) yet neither Lassell or Grubb have found this necessary for 4-feet specula. It is to be wished

that some ready means may be found for trying the diminution of light by tarnish. I think, if the image of a lucid disk were formed beside it at the centre of curvature, the two could be photometrically compared rapidly and without moving the speculum from the tube.

As to the ultimate possible size of a speculum of metal, an accident that occurred in casting a 6-feet, at which I was present, satisfied us that one of 7-feet could be made; nor is this the limit. But if the 4-feet "Foucault" just erected at Paris prove, as I hope it will, a great success, it is probably in that direction that the improvement of very large specula will tend. It will probably be difficult to form large glass disks with sufficient uniformity of strength in every direction, to resist distortion; but on the other hand, silver is so much more reflective than speculum metal,* that its equiluminous aperture will be only $\frac{2}{3}$rds of the other.

I look to this telescope with great interest; for, from it in conjunction with the great Refractor which is now in construction for the Observatoire, can alone be expected a really accurate comparison of the Achromatic and Reflector. As I have elsewhere stated, such comparison can only be fairly made when the conditions are identical; when the locality, the night, the object, the observer are the same; and I may add, when there is no personal or party bias in the judge. An observer becomes in some cases so much attached to his instrument as almost to identify himself with its character; and it may even happen that national feeling is interested in favour of a particular artist. All will be favourable at the Observatoire, and I trust that M. Le Verrier and his accomplished assistants will profit by so auspicious an opportunity.

On the Transit across the Sun's Disk of the Second or Great Comet of 1819. By J. R. Hind, Esq.

The second or great Comet of 1819 made its appearance in these latitudes under circumstances very similar to those attending the early visibility of the great Comet of 1861. It ascended above the north-west horizon as a conspicuous naked-eye object, and was very generally detected in Europe in the first days of July. The earliest observation for position appears to have been made by Professor Tralles at Berlin on the evening of the 1st of the month, and the latest observations were made by Struve at Dorpat and by Olbers at Bremen in the middle of October.

* The mean of Jamin's co-efficients for silver at perpendicular incidence is 0·90, which gives for the Newtonian 0·81, greater than that of most Achromatics. It is, however, doubted whether a film reflects as much as solid silver. A Committee has been appointed by the British Association to examine this, and some other cases of reflection.

He writes:—"Permit me to communicate to you yet another very curious observation which I found by accident in filing my old papers: it is not an observation made à la D'Angos; it is quite certain and made with the greatest precision. On the 26th of June, 1819, on looking at the Sun, I saw very distinctly upon its disk a nebulous spot and three black ones. The nebulous spot was perfectly round and slightly luminous. I am persuaded it was the comet, which, according to the calculations of M. Olbers, ought to pass over the Sun's disk June 26, 1819, at $5^h\ 47^m$ A.M. The roundness, the nebulosity, the luminous point in the centre appeared to me so remarkable, that I made a sketch as correctly as possible. At $8^h\ 26^m$ A.M. this nebulous spot was $84''{\cdot}5$ in diameter, and its distance from the south-east limb of the Sun was $6'\ 10''$. On the 27th of June, on looking at the Sun about 9 A.M., the nebulous spot, as well as one of the black spots, had disappeared. The other two black spots which on June 26 at $8^h\ 26^m$ A.M. were distant $36''$ and $34''$ respectively from the limb of the Sun, were already at a distance of $6'$ therefrom." Pastorff gives, for the position of Buchholtz: longitude $0^h\ 49^m\ 45^s{\cdot}5$ E. of Paris; latitude $52°\ 26'\ 50''$.

Canon Stark's observation at Augsburg is found in his *Meteorologisches Jahrbuch* which contains regular observations of solar spots. He states that at $7\frac{1}{2}$ A.M. on June 26, he saw a remarkable spot which "was neither like an opening nor shallow,' and in which there was no black depth (*schwarze Vertiefung*); the spot was small and not well defined. It was $15'\ 25''$ from the west limb and $14'\ 30''$ from the north limb of the Sun; hence not far from the centre of his disk. Stark adds that, at noon, his second hour of observation, the spot was no longer visible.

Some years since I calculated the circumstances of the transit of the comet across the Sun's disk, making use of the Parabolic Orbits of Dirksen and Nicolai, with Carlini's Tables for the Sun. The comet's positions from the two sets of elements were not found very accordant, and though confirming in general Olber's computation,* it appeared worth while to attempt a closer determination of the orbit, and this I have lately made. From observations between 1819, July 3 and October 12, by Gauss, Nicolai, Olbers, and Struve, I obtained the following parabola:—

T	1819, June 27·71547, Greenwich Mean Time.			
	°	′	″	
π	287	8	10·8	Mean Equinox, 1819, July 0.
Ω	273	41	56·8	
i	80	44	38·1	
$\log q$	9·5332327			

Motion direct.

* Bode's figure in *Berliner Jahrbuch*, 1823, is not drawn correctly.

Assuming for the semi-diameter of the Sun the Greenwich value at the Earth's mean distance, the apparent semi-diameter during the comet's transit would be 15′ 46″·0, hence at the time of Stark's observation the comet's calculated position is 13′ 18″ from the Sun's eastern limb, and 14′ 17″ from his southern limb; which position, compared with the observation, shows a difference of 2′ 49″ in R.A., and 2′ 45″ in Decl. For the time of Pastorff's observation, corresponding to $19^h\ 26^m\ 54^s$ Greenwich mean time, we have from the above numbers—

	′	″
Comet East of Sun's Centre	2	32
Comet North „ „	6	31

which differs widely from the position assigned by Pastorff—6′ 10″ from the Sun's south-eastern limb.

The small effect of parallax is neglected in both cases.

I have been favoured by Mr. Ranyard with a copy of Pastorff's drawing, the original of which, as already stated, is in the Society's archives. The object represented as having been observed upon the Sun's disk is certainly a very remarkable one, bearing every resemblance to the ordinary figure of a telescopic comet, and quite different from the forms of sun-spots. If, however, Pastorff really saw the comet upon the solar disk, his account of its position must be very erroneous.

Stark's position also is open to some doubt, though much nearer to that which the comet must have occupied at the time of his observation; it may perhaps be granted that he possibly saw the comet upon the Sun. Nevertheless, it is impossible not to remark the great difference between his description of its appearance and that given by Pastorff. It appears very improbable that a comet seen in projection upon the Sun's disk would present the cometary aspect which Pastorff describes; it is far more likely that the nucleus only would be discerned. If Pastorff's observation is a *bonâ-fide* one, what he really did see must remain an enigma. I will merely add in conclusion, that there are other observations of his which are exceedingly difficult of comprehension.

Note on the Displacement of Lines in the Spectra of Stars.

By W. H. M. Christie, Esq.

In recent Numbers of the *Comptes Rendus*, P. Secchi has called attention to some apparent discordances between the Greenwich results for the motions of stars in the line of sight, as given in the *Monthly Notices* for November 1875, and those obtained by Dr. Huggins, and has with justice pointed out that there are many difficulties attending all such observations. On these

this manner by the side of the regular image; and Mr. Hilger informs me that he has frequently obtained a perfect image of the sodium lines from one jaw of a slit, when the other has been removed. It is difficult to trace the origin of such false light; but I have found that it disappears when the incident-pencil is properly adjusted, and can therefore only suggest some such cause as I have indicated above. It was for this reason that the method of comparison by means of a vacuum tube placed within the great telescope in the course of the rays from the star was given up, although, in Dr. Huggins's hands, it certainly worked well. It would seem probable that the systematic error remarked in the measures between August 1874 and March 1875, was caused by reflection of some of the light from the sides of a small rectangular tube placed in the axis of the collimator close to the slit (to cut off false light), and that thus a false image was formed; in any case, the two pencils from the star and comparison-light, passing through different portions of the collimator-object-glass and of the prisms, might be affected differently by optical defects. The method now adopted of throwing an *image* of the comparison-light on the slit by means of a collimating lens and small reflecting prism, appears to be free from the errors to which the use of a reflecting prism alone is liable; certainly no erroneous shift of the comparison-line has been detected since it was brought into use. The adjustment of the slit to the principal focus of the telescope is another important condition, which has been specially provided for in the Greenwich Spectroscope by means of a diagonal prism, which can be pushed into the course of the rays close behind the slit, allowing the latter to be viewed at the same time as the star by a suitable eyepiece. This arrangement serves as a finder, and also as a means to verify the position of the comparison-light and star on the slit, which can thus be reduced in width until it limits the star's image on both sides; this will be seen to be a necessary condition for accurate comparison, when it is considered that one-thousandth of an inch at the slit corresponds, with the Greenwich Spectroscope (as ordinarily used for star motions), to about 15 miles a second in the motion of a star, whilst with such an instrument as P. Secchi's it would represent a much larger quantity. If P. Secchi had not used a sufficiently narrow slit, the appearances he describes of the star-line shifting its position when the driving clock of the equatoreal was stopped (allowing the star to travel across the slit) would be exactly accounted for.

I have entered into some detail on these matters, as the brief statement given in the *Monthly Notices* for last November seems to have been imperfectly understood, whilst P. Secchi apparently does not admit the propriety of rejecting the measures prior to 1875, May 31. These observations were given in order to show fairly the errors to which the method is liable, and the results could in any case only be considered as preliminary. In such an inquiry much experience is required, and large errors are there-

With regard to the amounts of the displacement, P. Secchi appears to be under a misapprehension, as it is in terms of the width of the narrow bright line of the vacuum tube, not of the broad line in the star, that the displacement is estimated. The great breadth of the latter in some stars (especially *Altair* and *Sirius*) constitutes one great difficulty of the observation, and the discordances in the case of *Altair* are, doubtless to be attributed to this cause, since a small error in the estimation of the centre of a broad band may easily be committed. Such a source of error will be sufficiently indicated by the discordances of the individual observations, independently of the notes of the observer; but there remains the question of the fixity of the centre of the F line as the pressure of the gas is increased. Dr. Huggins has fully discussed this point; and I need only refer to it to add that, by his kindness, I have had the opportunity of seeing his experimental verification of this fact. Independently of this, the fact remains that there is a relative displacement of the F line in the case of stars for which the breadth of the line is sensibly the same; besides which similar displacements are shown by the *b* lines (which are comparatively narrow), and accordant results have been obtained for the motion of *Arcturus* from the D, *b*, and F lines. An examination of the results for different stars on the separate nights of observation will show that the motions of approach and recession are fairly distributed; whilst the comparisons of the F line in the spectrum of the Moon (for which the motion is insensible) show conclusively that there is no systematic error arising from maladjustment of the spectroscope. In all the measures the greatest care has been taken to avoid bias, the observer being careful to make the bisection of the line in the spectrum of the star or Moon before that of the comparison spectrum was seen, and having generally no previous knowledge of the direction in which a displacement was to be expected. No observation has, under any circumstances, been suppressed, and consequently some of the measures might fairly be rejected on the ground of erroneous bisection.

Royal Observatory, Greenwich,
1876, *May* 12.

Spectroscopic Results for the Motions of Stars in the Line of obtained at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those prir the *Monthly Notices* for 1875, November, but for convenie reference, those of the former measures which are cons trustworthy are repeated, together with the more recent r and the means of the whole taken in the case of thos which have been satisfactorily observed. Where no mean down the result is to be considered as still uncertain. (vations have been enclosed in brackets and rejected in fo the means, in cases where no estimation of the displacemen made, or where the measured and estimated motions differ more than 50 miles a second. In the one case the circumst were evidently very unfavourable, in the other there is a s presumption of error. The estimated motions are given check on the micrometer measures, being made independ The motions actually observed may be inferred from concluded motions by algebraic addition of the correspo Earth's motion.

The weights given are on a scale of 1 to 5 for each mea in some few instances a weight of ½ has been given whe observation appeared very uncertain. The width of the sl been given, as this has an important bearing on the questi displacement; in some of the observations too wide a sli been inadvertently used, but recently care has been taken to the width to $3^{div.}$, or about 0·004 inch as a maximum. Th parent diameter of the image of a third magnitude star is $4^{div.}$, or 0·005 inch.

The only instrumental changes made since last Nove are: The adaptation to the small telescope of a bright-line m meter on a new principle, by Mr. Hilger, which has been regularly from 1875, November 29; an alteration in the ang the "half-prism" with which the train commences, so decrease the deviation of the pencil passing through it, by 5°, in order that it might pass through the other prisms o train at the angle of minimum deviation, and the insertion Barlow lens in the small telescope, increasing the power t These changes were completed 1876, February 18.

All the comparisons have been made by means of two parison-prisms in connection with a collimating lens, throwin image of the comparison-light on the slit, immediately abov below that of the star. The interval between these compar prisms can be decreased at pleasure, till they are brought contact.

The results which follow are arranged in order of R Ascension of the stars observed. The measures of the Moon been made as a check on the system of observation.

Royal Observatory, Greenwich,
1876, *May* 12.

Motions of Stars in the Line of Sight in Miles per Second.

(+ denotes Recession; − Approach.)

1 div. in the width of the slit corresponds to 0·0013 inch.

Date.	Observer.	No. of Measures.	No. of Prisms.	Width of Slit.	Lino.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
						α Andromedæ.			
1875 July 29	M	2	1½	d 2·6	F	−14·8	−14·7	−11·2	Star line faint; sky hazy; weight 2.
Aug. 4	M	2	1½	2·9	F	−14·1	− 6·5	−17·2	Indirect comparison; weight 2.
30	M	2	1½	2·6	F	− 9·5	−28·3	−36·0	Indirect comparison; star line rather faint from cloud; weight 2.
Dec. 17	M	2	2½	3·1 & 4·2	F	+16·3	−39·2	−44·9	Indirect comparison; star line rather faint, but better seen than on any previous occasion; weight 4.
22	M	2	2½	2·9	F	+16·7	−71·3	−79·6	Direct comparison; wind very high and images very unsteady; weight 2.
						Mean	−33·	−39·	
						Aldebaran.			
1875 Nov. 29	M	2	1½	2·7	b_1	− 0·3	(+135·0)	(+80·8)	Comparison doubtful, the lines being very faint, and there being several close together.
Dec. 17	M	1	2½	6·7	b_1	+ 5·7	+35·1	+48·7	Line confused with others near; weight ½.

						Castor.			
1875	Dec. 17	M	2	2½	5·5	F	− 7·3	+61·3	+41·1	Weight 4.
1876	Feb. 23	M	2	2½	2·1 & 2·2	F	+13·3	+24·2	+13·7	Very tremulous; weight 5.
	Mar. 17	M	2	2½	3·1 & 1·0	F	+17·0	+15·5	+22·5	Weight 8; direct comparison showed a slight displacement to red.
							Mean	+29·	+24·	
						Procyon.			
1875	Dec. 17	M	2	2½	5·0	F	− 8·6	+34·3	+35·1	Weight 4; lines appeared nearly coincident; images steady, but spectrum not bright.
1876	Mar. 17	M	2	2½	1·0 & 1·4	F	+15·9	+59·4	+54·5	Weight 9; direct comparison showed a displacement to red greater than *Castor* or *Sirius*.
	Apr. 3	M	2	2½	1·1	F	+17·3	+33·7	+19·7	Weight 6; line faint and ill-defined; direct comparison showed a considerable displacement to red.
							Mean	+46·	+39·	
						Pollux.			
1876	Mar. 15	M	2	1½	1·5, 1·9	b_4	+16·4	−127·9	−86·5	Star line very faint; measure rather wide; weight 3; telescope not very firm.
						Regulus.			
1876	Feb. 23	M	2	2½	0·6 & 1·4	F	+ 2·2	+11·6	+21·4	Weight 6.
	Mar. 17	M	2	2½	4·1 & 3·1	F	+ 9·1	+47·8	+43·9	Weight 7.
	Apr. 8	M	2	2½	1·9 & 2·9	F	+14·2	+32·1	+34·1	Weight 8; star line dark, but wind high.
	May 6	M	1	2½	1·4	F	+17·6	+32·8	+15·9	Weight 1; star line very faint, and measure doubtful.
							Mean	+32·	+33·	

Date.	Observer.	No. of Measures.	No. of Prisms.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
				d					*γ Leonis.*
1876 Mar. 15	M	3	1½	3·2, 2·5	b_1	+ 8·5	−71·3	−65·7	Star line not very pronounced; weight 6; telescope not very firm.
									β Ursæ Majoris.
1876 May 1	M	3	2½	3·0, 1·5	F	+12·6	+15·5	+15·4	Line evidently displaced to red, but neither spectrum nor line well seen; weight 7.
									α Ursæ Majoris.
1876 May 1	M	2	2½	1·5	F	+11·6	−37·1	−40·3	Direct comparison showed a slight displacement to blue; weight 4.
									β Leonis.
1876 Apr. 8	M	2	2½	1·9	F	+ 8·8	−32·7	−31·0	Star line exceedingly difficult to see; weight 2.
									Spica.
1876 Feb. 23	M	2	2½	1·8	F	−13·0	+37·2	+50·1	Definition poor; weight 4.
									η Ursæ Majoris.
1875 June 11	M	2	2	...	F	+10·3	(+37·4)	...	Star line very faint, and not often seen; readings uncertain.
25	M	2	2	22·4 & 9·5	F	+10·4	(−65·1)	(−102·2)	Star line scarcely visible; result uncertain, on account of the width of the slit.
July 12	M	1	2	2·3	F	+ 9·4	−43·5	−23·5	Star line very faint, and bisection uncertain; displacement small; weight 1.

Arcturus.

1876 Mar. 15	M	2	1⅛	2·2, 1·6	b_1	+ 7·1	−47·9	−43·7	Weight 10.
15	M	2	1½	3·0	D_2	− 7·1	−47·6	−33·5	Weight 2; D lines not seen nearly so well as the *b* lines.
Apr. 8	M	4	2½	0·9, 1·5	F	− 0·8	−16·0	−16·1	Weight 8; measures somewhat uncertain, as there was much mist, and the Moon was very bright.
May 6	M	2	2½	4·4	F	+ 6·4	−33·2	−47·0	Weight 4; very poorly seen.
						Mean	−35·	−34·	

ε Boötis.

1876 Mar. 15	M	2	1½	3·6	b_1	− 7·1	− 4·6	−13·3	Line faint; weight 4; image tremulous; telescope not very firm.

α Coronæ.

1875 June 25	M	1	2	1·5	F	+10·2	(−119·3)	(−30·5)	The two lines could not be directly compared; star line dark, and very broad and nebulous.
1876 Apr. 8	M	2	2½	2·2	F	− 4·7	+59·9	+45·5	Weight 1; measures very doubtful.

α Ophiuchi.

1875 June 25	M	2	2	2·7	F	+ 3·3	−26·6	−25·1	Indirect comparison; spectrum faint; star line slightly displaced to blue.
July 12	M	2	1½	2·1, 1·5	F	+ 7·1	(+154·3)	(+88·5)	Star line very faint, and not well seen.

Altair—continued.

31	M	1	2½	4·1	F	+ 2·2	+13·8	+21·2	The observations are discordant.
31	M	2	1½	4·1	F	+ 2·2	−22·2	...	
Aug. 4	M	2	1½	4·1, 2·4	F	+ 3·3	−86·8	−62·1	Direct comparison.
30	M	2	2½	2·5	F	+ 9·5	−61·4	−57·5	
Dec. 22	M	1	2½	...	F	+ 8·1	...	...	Star line seen considerably displaced to the blue, but no measures could be obtained.

α Cygni.

1875 July 29	M	2	1½	2·8, 2·2	F	− 4·1	(+58·1)	(+80·5)	Star line faint.
31	M	2	1½	3·6, 4·6	F	− 3·8	−69·7	−79·7	Indirect comparison; weight 6.
Aug. 2	M	2	1½	2·3, 1·9	F	− 3·6	−53·2	−47·6	Indirect comparison; weight 6.
30	M	1	2½	2·1	F	+ 0·5	(−20·7)	...	Nearly coincident.
30	M	1	1½	2·1	F	+ 0·5	−31·7	−35·5	Indirect comparison; weight 3.
Nov. 29	M	1	1½	4·4, 4·5	F	+ 9·7	−36·4	−33·4	Indirect comparison; star line faint; nearly coincident; weight 6.
						Mean	−50·0	−51·0	

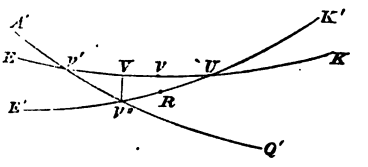
α Pegasi.

1875 July 29	M	2	1½	3·1, 3·6	F	−12·0	−10·3	−13·7	Indirect comparison; star line broad and dark; slightly displaced to blue; weight 4.
Aug. 4	M	2	1½	2·5	F	−10·7	−20·5	−14·8	Indirect comparison; weight 4.
30	M	2	1½	2·7, 3·1	F	− 4·3	−66·3	−39·5	Indirect comparison; weight 4.
						Mean	−32·	−22·	

Date.	Observer.	No. of Measures.	No. of Prisms.	Width of Slit.	Line.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
				d				*Moon.*	
1876 April 3	M	1	2½	...	F	...	− 2·6	...	Moon line very faint, much fainter than the line in *Procyon*, but not harder to bisect as it was of course narrow and sharp. The spectroscope seemed in good adjustment.
„	M	1	2½	...	F	...	− 0·3	...	
„	M	1	2½	...	F	...	+ 7·9	...	
„	M	1	2½	...	F	...	− 3·0	...	
„	M	1	2½	...	F	...	+ 1·3	...	
„	M	1	2½	...	F	...	− 0·8	...	
„	M	1	2½	...	F	...	+ 8·9	...	
8	M	1	2½	...	F	...	− 9·4	...	Moon line fairly well seen, but faint.
„	M	1	2½	...	F	...	+13·7	...	Sharp but faint.
May 1	M	1	2½	...	F	...	− 1·5	...	Line very faint, and more difficult to bisect than the line in the spectrum of a large star would be.
„	M	1	2½	...	F	...	+ 9·1	...	
„	M	1	2½	...	F	...	+10·1	...	
3	M	1	2½	...	F	...	+ 4·0	...	Moon line seen better than on any previous occasion.
„	M	1	2½	...	F	...	− 4·1	...	Not quite so good, but very nicely seen.
6	M	1	2½	...	F	...	− 5·3	...	Moon line very well seen, easier to measure than *Vega* even.
„	M	1	2½	...	F	...	+ 4·8	...	

On the General Precession. By Dr. Friedrich Wilhelm Berg.

Let EK be the ecliptic at the time T, E′K′ the ecliptic at the time $T+t$, and A′Q′ the equator at the time $T+t$; also let ν be the equinox at the time T, ν'' the equinox at the time $T+t$, ν' the equinox at time $T+t$, on the fixed ecliptic at the time T, and R that point in the ecliptic at the time $T+t$, which was at the time T in the ecliptic EK in ν. The arc $\nu\nu'$ is now called the Lunisolar Precession, and Rν'' the General Precession, both referring to the time $T+t$.



Now let us put

$$\nu\nu'=\psi,\quad R\nu''=\psi_1,\quad \angle U\nu'\nu''=\epsilon,\quad \angle U\nu''Q'=\epsilon_1,\quad \nu'\nu''=\lambda;$$

and since

$$U\nu = UR,$$

we obtain from the triangle $U\nu'\nu''$

$$\tan\frac{\lambda}{2}\cos\frac{\epsilon_1+\epsilon}{2} = \cos\frac{\epsilon_1-\epsilon}{2}\tan\frac{\psi-\psi_1}{2};$$

and, consequently, neglecting the third and the higher powers of the time, we have

$$(1)\qquad \psi-\psi_1=\lambda\cos\epsilon-\lambda\sin\epsilon\tan\frac{\epsilon_1-\epsilon}{2}.$$

Instead of the formula (1), Leverrier, in the *Annales de l'Observatoire de Paris*, vol. ii. p. 172, gives the formula—

$$\psi-\psi_1=\lambda\cos\epsilon,$$

drawing the arc Vν'' perpendicular to the ecliptic EK, and putting

$$V\nu'=\psi-\psi_1.$$

But the approximation cannot be admissible, and putting

$$\angle K'UK=\eta,\quad \nu U=\Pi,$$

we obtain, neglecting the third power of the time—

$$\lambda=\frac{\eta\sin(\psi+\Pi)}{\sin\epsilon}-\frac{\eta^2\sin(\psi+\Pi)\cos\Pi}{\sin\epsilon}\cot\epsilon,$$

$$\frac{\epsilon_1-\epsilon}{2}=\frac{1}{2}\left\{\eta\cos\Pi-\eta\psi\sin\Pi+\frac{1}{2}\eta^2\cot\epsilon\sin^2\Pi\right\},$$

and therefore we obtain, from (1),

$$\psi - \psi_1 = (g+\Gamma)\cot\epsilon . t$$

(2)

$$+\left\{\left(\nu + a\,(g'+\Gamma')\right)\cot\epsilon - \frac{1}{2}(g+\Gamma)\,(g'+\Gamma') - (g+\Gamma)\,(g'+\Gamma')\,\cot^2\epsilon\right\} t^2,$$

where (Leverrier, *loc. cit.*)

$$\eta \sin\Pi = (g+\Gamma)\,t + rt^2,$$
$$\eta \cos\Pi = (g'+\Gamma')\,t + r't^2,$$
$$\psi = at + bt^2;$$

and by substituting the numerical values, according to Leverrier (*loc. cit.*), we obtain from (2)

$$\psi - \psi_1 = 0''{\cdot}1356809\,t - 0''{\cdot}000221628\,t^2,$$
$$\psi_1 = 50''{\cdot}23572\,t + 0''{\cdot}00011282\,t^2.$$

Instead of these values, Leverrier gives (*loc. cit.*)

$$\psi - \psi_1 = 0''{\cdot}13568\,t - 0''{\cdot}00022170\,t^2,$$
$$\psi_1 = 50''{\cdot}23572\,t + 0''{\cdot}00011289\,t^2;$$

while the formula of Leverrier does not contain the term

$$-\frac{1}{2}(g+\Gamma)\,(g'+\Gamma').t^2.$$

Wilna Observatory,
1876, *Jan.*

Note on the Satellites of Uranus. By E. Neison, Esq.

With the view of ascertaining whether the two outer satellites of *Uranus* were within the reach of a Newtonian reflector of 9½-inch aperture, on the night of April 14, $8^h\ 0^m$ to $9^h\ 15^m$, the telescope was turned on the planet. The air was very steady, and definition very good. After putting *Uranus* into the field of view, this was constricted to a diameter of about 2′, and the neighbourhood of the planet carefully examined for faint stars. After a prolonged and very careful search two were picked up, the planet all the time being kept beyond the field of view. Whilst looking at the fainter of the two, which was only seen with difficulty, the planet accidentally sailed into the field, without however in any manner interfering with the distinctness of this very faint object. It was found to be sensibly as easy to pick up the two stars with the planet in the field as with the planet out.

The distance and position-angle of the two stars were estimated as well as possible, with the following result:—

A	Very faint and difficult	Distance 15″–20″	Pos.-Angle 270°–280°
B	Fairly distinct	Distance 30–40	Pos.-Angle 100–110

On referring the next morning to the Ephemeris of Marth, it was found no satellite was in the position of the star B, but that A agreed well with the position of the III Satellite *Titania*, whose place was—

III Satellite, *Titania*	Distance 18″	Pos.-Angle 285°

The next night, April 15, being also very clear and steady, *Uranus* was again examined with a field of 2′ in an eyepiece magnifying 270, and, after a very careful search, three faint stars picked up.

C	Very faint	Distance 15″–20″	Pos.-Angle 230°–240°
D	Slightly brighter than C	Distance 30–40	Pos.-Angle 160–170
B	Bright and distinct	Distance 50–60	Pos.-Angle 100–110

On the next morning it appeared that the two faint stars C and D agreed to some degree of approximation with the positions of the III and IV Satellites, whose places were—

III Satellite, *Titania*	Distance 24″	Pos.-Angle 223°
IV Satellite, *Oberon*	Distance 44	Pos.-Angle 180

The third star B was obviously the same star as that seen the previous night and marked B, the planet having moved about 20″ further from it.

During the next week no night appeared to possess sufficient excellence of definition to render it worth while to turn the telescope on *Uranus*.

The 23rd of April turned out a fine, steady night, and from 8.30 to 9.15 the planet was examined. Two stars were picked up.

E	Very faint; only just visible	Distance 20″–25″	Pos.-Angle 320°–330°
F	Only suspected	Distance 40–50	Pos.-Angle 70–80

Reference to Marth's Ephemeris next day showed that E agreed to a certain extent with the position of the IV Satellite *Oberon*, whose place was

IV Satellite, *Oberon*	Distance 33″	Pos.-Angle 338°

The suspected star F, if it really existed, must have been a fixed star.

The night of April 25 was the finest night of the year, and no less than six stars were seen or suspected.

G	Very faint indeed; only suspected	Distance	35-40	Pos.-Angle 290-3
H	Comparatively distinct	Distance	60-80	Pos.-Angle 100-1
I	Faint, but fairly well visible	Distance	25-30	Pos.-Angle 250-2
B	Distinct and bright	Distance	120-140	Pos.-Angle 90-1
J	Very faint, and generally only glimpsed	Distance	20-25 or perhaps 30	Pos.-Angle 140-1
L	Large bright star, 3′ or 4′ off, that had been seen on the 23rd, and preced *Uranus*.			

On the next day it was found that, according to the Ephe meris, I was the IV Satellite, probably *Oberon*, and J migh have been the III Satellite *Titania*, the places being

III Satellite, *Titania*	Distance	32	Pos.-Angle 188
IV Satellite, *Oberon*	Distance	25	Pos.-Angle 253

The star B agreed in position with the star B seen on the nights of April 14 and 15.

Since April 25 moonlight has prevented further observations of the satellites or pseudo-satellites of *Uranus*.

On mapping down out of mere curiosity the places of the different stars seen around *Uranus*, on one plan, allowing for the motion of the planet, an entirely unforeseen result presented itself, when the stars seen on April 25 were inserted. For it was found that the star H seen on this night must have been on April 15 close to *Uranus*, its place being between Distances of 20″–30″, and Position-Angles 180°–220°. Considering the difficulty of estimating the distances and position-angles of these faint stars, it is perfectly possible that what was taken for the IV Satellite of *Uranus* on April 15 may have been this star, which was close to the place of the Satellite. It also appeared that the star G, which was suspected on the night of the 15th must, if it really existed, have been not far distant from the star seen on the 23rd in the position of the IV Satellite *Oberon*. Its place must have been between Distances 22″–27″, and Position-Angles 285°–300°. It is not however so likely as in the former instance, that this suspected star is what was seen, and taken for the Satellite of *Uranus*, since the position-angles differ considerably.

The point possesses, however, considerable interest, for it shows that a faint star being very approximately in the theoretical position of the satellite, is no proof that it actually is the satellite. The present observations show, however, that very probably the III Satellite *Titania* was seen on two occasions, and perhaps on a third; whilst the IV Satellite *Oberon* appears to have been seen for certain on one night, probably on another, and perhaps on a third.

On the Visibility of Oberon and Titania.

By George R. Rogerson, Esq.

Referring to Mr. Webb's communication to the Society at the meeting held on the 12th ult., on the subject of Mr. Ward's observations of the two exterior satellites of *Uranus*, Mr. R. C. Johnson (recently elected a Fellow of the Society) on the 25th of January, 1871, at 8.30 P.M., with a 9-inch silvered glass Newtonian by Browning, distinctly saw the two exterior satellites. The powers used varied from 200 to 650. Both were easily seen at once without previous knowledge of their positions, and *Titania* seemed only very slightly fainter than *Oberon*. Mr. Johnson frequently observed them afterwards, but considered them so easy to find that he only once entered them in his Note-book. Mr. Johnson tried to find the inner satellites, but, of course, without success.

Mr. Johnson thinks that with an 8 or 8½-inch aperture they would be perceptible.

Waterloo Cottage, Liverpool,
1876, *May* 11.

A Catalogue of Red Double Stars.

By S. W. Burnham, Esq.

The following is a list of Double Stars situated within 121° of the North Pole, where one of the components has been set down as red in a greater or less degree, and is intended to include only such stars as are not found in the revised and enlarged edition of Schjellerup's *Catalogue of Red Stars*. These objects depend largely for their insertion here upon the authority of Sir John Herschel, and his partiality for red tints, long ago remarked, should be borne in mind, as in some cases later examination by other observers has shown the colours to be much less decided, or almost entirely wanting; but I have thought it better for the present to make the list nearly complete, leaving the work of making from all sources of information a carefully selected Catalogue of stars really red to some one more specially interested in this subject. Incidentally I have found many of these pairs from time to time, and in some instances have failed to notice any very positive red colour, but as these observations had for the most part a different object in view, I do not regard them of sufficient value to be recorded here.

The measures and magnitudes are generally from the Double Star Catalogues from which the pairs are taken.

Chicago, 1876, *April* 15.

No.	Designation.		R.A. 1880. h m s	Decl. 1880. ° ′	Pos.-Ang. °	Distance. ″	Mags.	Notes.
1	Σ 8	*Ceti* 27	0 5 25	− 3 45	292·6	7·31	7·2...8·8	*Subflava*; *cinerea*: Struve. Both red: South and Herschel.
2	Σ 11	...	0 8 20	+77 21	192·1	7·95	8·2...10·7	8·2 *subflava*: Struve. Large star *very red*: Hers.
3	Σ 46	55 *Piscium*	0 33 36	+20 47	192·7	6·37	5·0...8·2	*Egregie flava*; *eg. cærulea*: Struve. *Yellow*; *deep red*: Dembowski.
4	H. 626	W² O. 986	0 39 7	+31 1	330°	20·±	9...14	Large star *very red*: Herschel.
5	H. 628	W² O. 1137	0 45 25	+33 14	65·±	35·±	7...16	Large star *very red*: Herschel.
6	H. 1066	O³ Arg. 1080	0 59 1	+62 2	302·2	6·±	9...14	Large star *ruddy*; small more so: Herschel.
7	H. 2079	Arg. (52°) 434	1 38 33	+52 50	300·±	8·±	9–10...15	Large star *very red*: Herschel.
8	H. 3461	*ε Sculptoris*	1 40 1	−25 39	72·5	3·±	6 ..10	Large star *white*; small *dull red*: Herschel.
9	Σ 163	O² Arg. 2027	1 42 35	+6416	33·6	34·93	6·2 ..8·2	*Rubroaurea*; *cærulea*: Struve.
10	H. 644	W¹ I. 736	1 42 22	+ 7 5	277·	15·±	8...14	Large star *very red*: Herschel.
11	Σ 188 *rej.*	...	1 50 47	+62 20	236·6	40·±	9...10	Very red; fine green: Herschel. (4th Cat.)
12	H. 647	W¹ I. 980	1 56 18	+ 7 6	50·±	30·±	10...10–11	Large star *deep blood red*, a very intense and remarkable colour; small star *green*: Herschel. The principal star is 9 mag. in Weisse. Position-angle appeared too large, and colour not very striking with 6-in.: Burnham.
13	H. 2129	Arg. (76°) 79	2 15 50	+76 40	159·4	10·±	10...14	Large star *very red*: Herschel. In Arg. mag. 9·5.
14	H. 652	...	2 26 7	+ 9 3	320·±	2½·±	10...10+	Elegant; *both ruddy*: Herschel.
15	H. 653	W² II. 598	2 26 26	+30 53	43·±	17·±	9...12	*Orange red*; *blue*: Herschel.
16	H. 2146	...	2 29 30	+76 18	82·5	30·±	10=10	Both stars *red*: Herschel.

17	H. 2166	...	2 53 55	+75 19	251·3	40″ ±	8·9...10	Large star *very ruddy*: Herschel.
18	H. 2168	...	2 56 30	+70 58	294·1	12″ ±	10...11	Large star *very red*: Herschel.
19	H. 2173	L. 5686	3 2 13	+73 25	164·3	25″ ±	6–7...12	Large star *very ruddy*: Herschel.
20	Σ 416 *rej.*	...	3 28 2	+19 24	44·7	25″ ±	9...10	*Red*; *blue*: Herschel (5th Cat.)
21	H. v. 13	ϕ *Tauri*	4 12 58	+27 4	241·8	55·9	6...8½	*Light red*; *cerulean blue*: Smith. *Red*; *bluish*: South and Herschel.
22	H. 344	Arg. (33°) 883	4 28 26	+33 41	95″ ±	10″ ±	10...14	Large star *very red*; small *dusky red*: Herschel. An observation in 7th Cat. gives magnitudes 8...9. Feb. 1876, *reddish*; magnitudes 8½...14: Burnham. The largest star is 8·4 mag. in Arg.
23	Σ 579	...	4 34 32	+22 30	30·1	16·48	8·5...10·7	8·5 *rubroflava*: Struve.
24	H. 2244	Rad. 1356	4 52 16	+69 12	166°	100″ ±	9...9	Both stars *remarkably red*: Herschel. The other star is R. 1357.
25	Σ 649	W¹ IV. 1399	5 2 35	− 8 49	80·8	21·59	7·0...8·7	*Alba*; *cærulea*: Struve. *White*; *very ruddy*: Herschel (*Cape Obs.*)
26	Σ 648	W² IV. 1453	5 3 14	+31 53	74·3	4·68	7·4...8·1	*Subflava*; *subcærulea*: Struve. In two observations Dawes calls the large star *red*, or *reddish*.
27	H. 3752	P. V. 70	5 16 51	−24 54	110·1	2·86	6...8	White; red: Smyth.
28	H. 701	Arg. (31°) 992	5 22 48	+31 25	...	...	9...15	Large star *very red*: Herschel. The mag. in Arg. is 7·1.
29	Σ 724	W¹ V. 530	5 23 36	+10 55	241·5	6·86	8·7...10	Small star *very red*: Herschel. (7th Cat.)
30	Σ 783	...	5 37 0	+28 58	358·8	9·81	8·0...9·7	*Eg. alba*; *rubropurpurea*: Struve. *White*: Secchi.

No.	Designation.		R.A. 1880. h m s	Decl. 1880. ° ′	Pos.-Ang. °	Distance. ″	Mags.	Notes.
31	Σ 790	*Orionis* 187	5 40 5	− 4 19	89·1	6·82	7·0...9·3	*Rubroflava*; *cærulea*; colores insignes: Struve.
32	Σ 823 = H. 375	W² V. 1294	5 51 56	− 7 40	339·3	7·50	8·5...9·2	*Albæ*: Struve. *Both red*: Herschel.
33	H. 3823	...	5 55 53	−31 4	131·5	3·±	9=9	Both stars *orange* or *even red*; very decided colours: Herschel.
34	Σ 840	...	5 59 48	+10 46	247·2	21·14	6·2...8·5	A and B C } B C *rubea*; D¹ = 0″·55 (1857·1): Secchi.
					183·4	0·91	8·7	B and C }
35	Σ 875	W¹ VI. 142	6 6 37	−13 7	334·9	6·05	8·7...9·8	*Red*; *very green*: Herschel (*Cape Obs.*)
36	H. 383	...	8 34	− 2 39	285·±	2·±	10...10	Both very ruddy: Herschel.
37	H. 3845	...	12 1	−22 40	51·3	25·±	8...12	Large star *ruddy*: Herschel.
38	Σ 895 *rej.*	W² VI. 372	6 14 23	+ 5 48	59·8	40·±	8–9...11	In two observations Herschel notes the larger star as *red*, and *very red*, and the comp. *blue* and *green*. Later the colours are given as *orange*; *fine blue*.
39	H. 725	...	6 14 24	+ 9 47	75·±	20·±	8·9...10	*Ruddy*; *purplish blue*: Herschel.
40	H. 735	W² VI. 895	6 32 6	+35 32	80·±	3·±	9...11	*Ruddy*; very elegant: Herschel.
41	Σ 983 = H. 403	...	6 48 14	+34 37	36·6	11·85	7·7...11·7	7·7 *flava*: Struve. *Red*; *bluish*: Herschel.
42	H. 412	Arg. (24°) 1531	6 59 48	+24 22	20·±	35·±	7...17	Large star *red*: Herschel.
43	H. 756	...	7 14 2	+34 55	60·±	10·±	9·10...15	Large star *red*: Herschel. This pair is indentical with H. 417, but no mention of colour in that observation.
44	S.B. 198	L. 14503	7 20 36	−20 43	212·	3·5	8...11	Large star *red*: Burnham.

45	H. 2391	O¹ Arg. 6862	7 23 9	−26 36	292·2	15·±	8–9...14	Large star *very red*: Herschel.
46	H. 3973	...	7 26 36	−20 41	36·3	8·±	9...10	Pure *white*; remarkable *brick red*: Herschel.
47	H. 772	...	7 54 0	+35 46	35·±	5·±	11...12	A *red* star 7ᵐ 2ˢ distant in the direction of 120°: Herschel.
48	Σ 1202	P. VIII. 13	8 6 59	+11 13	325·3	2·03	7·7...9·8	Binary; 7·7 *alba*: Struve. *Reddish*: Dawes.
49	S.B. 207	L. 17091	8 33 44	−19 19	103·5	4·40	6·5...10·5	Decidedly *reddish*: *blue* (?): Burnham.
0	H. 110	a^2 *Cancri*	8 51 54	+12 19	320·±	10·±	4–5...20	*White*; *red*: Herschel. Dembowski has measured this with 7½-in., and calls the small star 11·0 mag. of Struve's scale.
51	H. 121	...	9 7 9	+10 21	70·±	1·±	10...	Both *red*: Herschel.
52	Σ 1371	W² IX. 615	9 29 10	+ 4 27	279·8	7·11	8·0...10·5	Small star *dusky red*; a very remarkable colour: Herschel (5th Cat.)
53	H. 149	...	9 54 46	+ 5 36	265·±	30·±	...	*Red*; *purple*: Herschel.
54	H. 159	W¹ X. 209	10 14 3	+11 57	15·±	35·±	8...10	*Red*; *blue*: Herschel.
55	H. 183	W. XI. 529	11 31 48	+13 37	20·±	60·±	...	*Red*; *bluish*: Herschel. In Weisse, 8 mag.
56	H. 506	...	11 32 26	+38 51	135·±	15·±	7...15	Large star *red*: Herschel. There is certainly no such star in this place. Exactly 1° North is a yellowish 7 mag. star, but I could not see any companion with 6-in., though carefully looked for. There is nothing in H.'s place brighter than about 10 mag.
57	H. 1201	B.A.C. 4005	11 44 48	+12 54	189·0	12·±	6–7...13	Small star *red*: Herschel. The principal star 6 mag. in Arg.
[illegible]	H. v. 121	12 *Comæ*	12 16 28	+26 31	168·2	66·1	5...8	*Straw-yellow*; *rose-red*: Smyth.
	1664	W¹ XII. 508	12 32 6	−10 51	254·7	19·44	7·7...8·8	*Flava*; *cærulea*: Struve. *Red*; *blue green*: Herschel (*Cape Obs.*)

	Designation.		R.A. 1880. h m s	Decl. 1880. ° ′	Pos.-Ang. °	Distance. ″	Mags.	Notes.
60	H. 1221	...	12 37 56	+74 11	260·±	...	...	Fine coarse double star. *Red*; *blue*: Herschel.
61	...	Lac. 5686	13 42 15	−27 46	110·2	77·	7...10	A beautiful deep red or crimson star, with a distant bluish companion. This was found after the completion of this list (April 17, 1876). Called 8 mag. by Arg. and 7·7 in Washington Catalogue, and may therefore be variable. Companion approximately measured.
62	H. 1249	O¹ Arg. 13508	14 10 25	−15 53	167·7	6·±	8–9...11	"The large star a fine red, between rose and garnet. It is rather a florid than a deep blood-red": Herschel. In the 5th Cat. it is described, "large star very high red, between orange and ruby."
63	H. 546	B.A.C. 4777	14 18 48	−12 49	40·±	30·±	5·6...11	*Red*; *blue*: Herschel. The correct place is given, Herschel's being erroneous in R.A. and Decl.
64	Sh. 184	54 *Hydræ*	14 39 4	−24 56	136·7	10·	5·5...7·5	Red; blue: South and Herschel.
65	Σ 1894	18 *Libræ*	14 52 24	−10 40	38·7	19·4	6·0...10·2	6·0 *subflava*: Struve. *Straw colour*; *grape red*: Smyth.
66	H. 2772	O. Arg. 15242	15 11 32	+45 18	309·	10·±	9–10...13	*Both ruddy*: Herschel.
67	H. 4767	...	15 17 58	−26 20	140·±	30·±	8½...11	*Red*; *blue*: Herschel.
68	Sh. 239	43 *Herculis*	16 40 4	+ 8 48	230·9	80·09	5...9	*Decidedly red*; *bluish*: South and Herschel. *Rose tint*; *light blue*: Smyth. *Golden*; *blue*: Demb.
69	H. 1294	L. 30509	16 40 56	−24 19	136·±	18·±	7...17	Large star *red*: Herschel.
70	Σ 2110 *rej.*	56 *Herculis*	16 50 6	+25 56	96·	15·±	6½...13	*Light yellow*; *pale red*: Smyth. *Reddish*; *bluish white*: South and Herschel.
71	Σ 2253	W¹ XVII. 1073	17 52 55	+14 38	80·4	18·1	7·5...10·2	7·5 *subflava*: Struve. Large star *red*: Herschel.

72	Σ 2264	95 *Herculis*	17 56 24	+21 36	261·7	6·06	4·9...4·9	*Flavasubviridis*; *flavasubrubra*: Struve. *Light apple-green*; *cherry-red*: Smyth. *Pale red* to *orange*: Dawes.
73	H. 2832	...	18 20 58	−21 19	15·0	18·±	9·10...11	Large star *very red, almost ruby*: Herschel.
74	Σ 2319	W² XVIII. 607	18 22 30	+19 13	191·0	5·61	7·2...7·6	*Albæ*: Struve. Both stars *pink*: Dawes.
75	H. 5499	...	18 32 10	− 4 25	155·±	15·±	9...12·5	Large star *very red*: Herschel.
76	H. 1322	...	18 33 47	+24 33	224·0	18·±	8...11	Small star *ruddy*: Herschel.
77	H. 1337	W² XVIII. 1064	18 36 22	+31 28	174·9	6·±	9...12	Small star *ruddy*: Herschel.
78	H. 2852	...	18 57 16	+ 7 14	134·5	18·±	10...12	*Red*; *blue-green*: Herschel.
79	H. 1365	...	19 0 21	+26 57	327·5	15·±	9–10...10	*Ruddy*; *green* by contrast: Herschel.
80	H. 881	Schj. 7257	19 11 43	− 5 38	340·±	30·±	7	A and B } Curious case of contrasted colours. Large
					310·±	3·±	11...11	B and C } star *red*; small stars *blue*: Herschel.
81	H. 1453	...	19 50 41	+24 20	227·1	23·±	9=9	The preceding star *reddish*: Herschel.
82	...	...	19 55 25	+ 0 20	*s.p.*	10·±	9–10...15	*Red*; *blue*: Harvard Zones.
83	H. 1470	L. 38428	19 59 18	+37 59	332·5	25·±	8–9...10	*Ruddy-yellow*; *contrasted green*: Herschel. *Rubra*; *cærulea*; colori superbi. Secchi. Mags. 7...8; called "Nova." The double star H. 605 having nearly the same R.A., but Decl. uncertain, given as between 38° and 40°, is undoubtedly identical with this. It is there described as *dark red*; purple; P = 340·°±; D = 20·″±; mags. 9...12. Both stars are observed by Arg. magnitudes 7·2...9·4.
84	H. 1529	...	20 27 0	− 6 38	114·0	25·±	7·8...11	Large star *red*: Herschel.
85	H. 2988	...	20 35 52	+ 2 32	139·7	20·±	9...11	Large star *very red*: Herschel.

No.	Designation.		R.A. 1880. h m s	Decl. 1880. ° ′	Pos.-Ang. °	Distance. ″	Mags.	Notes.
86	H. 1582	...	20 45 12	+38 5	328·0	25·±	9–10...12	Large star red: Herschel.
87	H. 2985	B.A.C 6999	20 46 27	+88 57	289·4	60·±	5–6...13	A *ruddy* bright star: Herschel.
88	H. 3005	...	20 48 6	+ 3 30	292·2	18·±	8–9...12	Large star *very red*: Herschel.
89	H. 5265	...	21 15 11	−22 53	196·7	20·±	9...9½	*Red*; *blue*: Herschel.
90	Σ 2790	B.A.C. 7417	21 15 55	+58 7	46·5	4·54	5·6...9·9	*Eg. rubra*; *cærulea*: Struve. *Orange*, 1871: Webb.
91	H. 1650 = O Σ 440	B.A.C. 7476	21 24 16	+59 14	189·6	12·2	6·2...11·0	6·2 *orange*; *red*: Herschel. *Jaune orange*: Dembowski.
92	H. 1669	O² Arg. 12555	21 32 1	+49 57	239·8	12·±	8...13	White; red: Herschel.
93	Σ 2850	...	21 54 16	+23 22	263·2	2·83	7·2...11·2	7·2 *rubroaurea*: Struve.
94	Σ 2895	W² XXII. 314	22 15 8	+24 21	6·1	4·80	8·5...10·0	8·5 *flava*: Struve. Red: Herschel. (5th Cat.)
95	Σ 2913	W¹ XXII. 477	22 24 14	− 8 44	331·9	8·01	7...8	*Alba*; *subrubra*: Struve.
96	H. 296	...	22 24 41	+12 32	220·±	12·±	9...11	Large star *ruddy*: Herschel.
97	O Σ 478 = Σ 2942	B.A.C. 7931	22 38 39	+38 50	280·6	2·80	6·0...8·4	*Aurorosea*; *cinerea*: Struve. *Cord. d'or*; *cendré*: Dembowski. B *very red*: Wilson and Seabroke. Error of 2ᵐ R.A. in *Mens. Micr.*
98	H. 3152	L 44810	22 48 40	+10 1	135·4	3·±	9...15	Large star *very red*: Herschel.
99	H. 975	W² XXII. 1133	22 50 9	+35 43	235·±	50·±	6...9	*White*; *red*: Herschel. This is No. 239 of the Pulkowa Cat. of wide pairs.
100	H. 1839	...	22 54 52	+40 29	293·5	15.±	10...12	Small star *dusky red*: Herschel.
101	S.B. 181	*Aquarii* 286	23 7 31	−14 3	309·8	1·42	7.0...10·5	Large star *reddish*—decided contrast in the two: Burnham. Measures by Dembowski.
102	Σ 3038 = H. 1907	...	23 40 23	+62 0	274·9	4·36	9...9·5	*Albæ*: Struve. {Both} *very red*, almost ruby colour: Herschel.

Note on Dr. Royston-Pigott's Starlit Transit Eye-piece.

By Capt. Wm. Noble.

Having been favoured, through the kindness of Dr. Royston-Pigott, with one of the Starlit Transit Eye-pieces, described by him before our March meeting, I have thought that a short Note on the result of the experiments which I have, so far, been able to make with it, may not be wholly destitute of interest.

Briefly then, I may say that I find that the mean transit of a star over the five lines ruled upon the silvered glass surface, differs some 0·3 or 0·4 second from that of its passage over (or through) the central line; and, inasmuch as the intervals between any two adjacent pairs of lines may be held to be mathematically equal, this affords a very fair indication of the degree of accuracy attainable with Dr. Royston-Pigott's most ingenious contrivance.

With my 4·2-inch Equatoreal of 61 inches focal length, the eye-piece I have gives a measured power of exactly 84.

A noticeable effect is produced by the passage of a "ghost" of every object observed, in a diametrically opposite direction, across the field.

Forest Lodge, Maresfield, Sussex,
1876, *May* 11.

Note on Coggia's Comet (III. 1874).

By J. Dreyer, Esq.

The accompanying sketches of the great Comet of 1874 were made by me while working at the Copenhagen Observatory with the refractor of 11-inches aperture. As the attention was principally directed to micrometrical observations, exact sketches of the head of the Comet were only made on three nights, June 20, July 13 and 16. I have thought they might be of some interest to the Fellows of the Society as a supplement to the drawings published in the March number of the *Monthly Notices.*

On the 20th June the nucleus was equal to a star of the fifth magnitude and the light in front of it was like the top of a fountain.

On the 13th July the Comet appeared as represented in the second sketch. The following branch was brighter than the preceding one. Two luminous tails streamed out from the foremost part of the coma, turning back left and right. They were decidedly brighter than the region round the nucleus. A faint parabolic arc of light was seen in front of these tails. The

nucleus was pretty sharply defined and formed the centre of a small sector of light, which faded away gradually. The sketch was taken at 11^h M.T.

On the 16th July the Comet was so near the horizon, that faint details could not be seen. The drawing was made at 10^h 20^m M.T. The two tails were seen again, but now streaming out directly from the nucleus. The preceding one could be traced out to the periphery of the parabolic coma, while the following one was shorter and faded away following.

June 20. July 13. July 16.

Coggia's Comet (III. 1874).
As seen with the 11-in. Refractor at Copenhagen.

The Earl of Rosse's Observatory,
1876, *May.*

Note on the Conjunction of Venus and λ *Geminorum on* 1876, *August* 17–18. By E. Dunkin, Esq.

Dr. Krüger, of Helsingfors, has drawn the attention of the Astronomer Royal to a very close approach of *Venus* to the star λ *Geminorum* on the morning of August 18 next, and he remarks that an opportunity will thus be afforded at the Northern and Southern observatories for making simultaneous micrometrical-measures of the distance between the planet and the star, the latter being, according to the *Uranometria Nova* of Argelander, of the 4–3 magnitude, and according to Heis, of the fourth magnitude. As a series of measures made in both hemispheres would be of some importance, it may be useful, for the convenience of observers, to insert in the *Monthly Notices* the tabular R.A. and N.P.D. of *Venus* for short intervals during the morning of August 18, and also the apparent place of λ *Geminorum* for the same day, deduced from the Greenwich *Seven-Year Catalogue* for 1864. Viewing this interesting conjunction as one of more than usual value, it is hoped that attempts will be made on this side the Atlantic to secure some micrometrical-measures, although the nearest approach occurs in Europe several hours after sunrise; but the star being of a fair magnitude, it is possible that at, or slightly before that time, it may be observable with some of our large telescopes. In North and South America, where the

nearest approach takes place before sunrise, measures may be made at the most favourable time without any difficulty.

The apparent R.A. and N.P.D. of λ *Geminorum* on August 18, are—

R.A.			N.P.D.		
h	m	s	°	′	″
7	10	59·30	73	14	8·17

The relative positions of *Venus* and the star may readily be found from the following interpolated hourly places of the planet, deduced from the daily places in the *Nautical Almanac*, and compared with the apparent R.A. and N.P.D. of the star given above:

Greenwich Mean Time, 1876.		R.A. of *Venus*, interpolated from *N.A.*			N.P.D. of *Venus*, interpolated from *N.A.*			R.A. of *Venus* −R.A. of Star.	N.P.D. of *Venus* −N.P.D. of Star.	
d	h	h	m	s	°	′	″	s	′	″
Aug. 17	16	7	10	31·97	73	16	3·7	−27·42	+1	55·5
	17		10	36·58		15	57·6	−22·81	+1	49·4
	18		10	41·20		15	51·6	−18·19	+1	43·4
	19		10	45·83		15	45·5	−13·56	+1	37·3
	20		10	50·48		15	39·5	− 8·91	+1	31·3
	21		10	55·14		15	33·5	− 4·25	+1	25·3
	22		10	59·81		15	27·5	+ 0·42	+1	19·3
17	23		11	4·49		15	21·5	+ 5·10	+1	13·3
18	0		11	9·18		15	15·5	+ 9·79	+1	7·3

The apparent semidiameter of *Venus* at the time of nearest approach on August 17, 22^h is $19''·1$.

It may be remarked that the nearest approach occurs half-an-hour before sunrise at Washington, *Venus* being about 27° above the horizon. At Santiago de Chile the planet will be about 12° above the horizon at this time, or nearly an hour-and-a-half before sunrise.

The favourable positions of observatories in America is, however, better shown by the numbers in the following table, which gives the local mean times of the conjunction of the planet and star in R.A. and of sunrise, together with the corresponding altitude of *Venus* for the Observatories of Ann Arbor, Washington, and Santiago de Chile:—

		Local M.T. of Conjunction.			Local M.T. of Sunrise.			Altitude of *Venus*.	
		d	h	m	d	h	m	°	′
Ann Arbor	Aug.	17	16	21	17	17	16	21	35
Washington	,,	17	16	48	17	17	22	26	32
Santiago	,,	17	17	13	17	18	38	12	5

Kidbrooke, Blackheath,
1876, *May* 6.

Note on the Discovery of Four Minor Planets, (160) *Una,* (161), (162), *and* (163). By E. Dunkin, Esq.

Since the tabular statement given on page 189 of the last Annual Report was prepared, four additional planets have already been discovered. The detection of so many new members of the group of planetoids of about the twelfth magnitude, leads us to believe that the group contains a large and probably indefinite number of planets even more minute than those which are known to exist, and consequently our interest in these frequent planetary discoveries has of late considerably diminished. But so long as observers continue to have the zeal to search for new planets, it is important that a current record of each discovery should be inserted in the *Monthly Notices*, for reference, as soon as possible after its announcement, although it is usual to give an annual summary of the year's planetary discoveries in the next Report of the Council. This duty naturally falls on the Secretaries, and I have therefore collected together from different sources the following early observations of the four new planets made at European observatories to the end of April.

Minor planet (160) *Una* was discovered by Dr. C. H. F. Peters at the Litchfield Observatory, Clinton, New York, on 1876, February 20. Magnitude the twelfth. From observations made at Clinton on February 24, and at Berlin on March 16 and 31, Dr. A. Schmidt has calculated the following elements:

Epoch: 1876, March 16·5, Mean Time Berlin.

		°	′	″	
M	=	93	31	20·7	
ω	=	47	31	29·3	Mean Eq. 1876·0.
Ω	=	9	18	3·3	
i	=	3	51	16·6	
ϕ	=	3	27	44·6	
μ	=	785″·136			
log a	=	0·436708			

Minor planet (161) was discovered by Mr. Watson at Ann Arbor, Michigan, on April 18. A telegram was received by the Astronomer Royal from the Smithsonian Institution on the evening of April 19, which was communicated to the daily newspapers without delay. "Planet; Watson; R.A. = $13^h\ 28^m$; Decln. = 11° 45′; daily motion 2′ north; magnitude eleven." The following early observations of the planet have been made in Europe.

1876.	Mean Time. h m s		Observed R.A. h m s	l.f.p.	Observed N.P.D. ° ′ ″	l.f.p.	Mag.
April 20	11 28 58	Berlin	13 27 10·44	7·107	101 43 10·2	0·901	10·5
20	15 17 22	Marseilles (*a*)	13 26 58·74	9·573	101 42 41·4	0·826	11·0
22	10 2 26	„ (*a*)	13 25 4·23	9·173	101 39 14·5	0·858	11·0
22	12 34 45	Paris	13 24 56·76	9·110	101 39 6·5	0·887	
23	12	Lund	13 23 51		101 36 54		
30	13 26 16	Berlin	13 16 45·83		101 23 58·9	0·886	

Minor planet (162) was discovered by M. Prosper Henry at the Observatory of Paris on April 21. It was of the twelfth magnitude. The following early observations have been communicated to the Society:

1876.	Mean Time. h m s		Observed R.A. h m s	l.f.p.	Observed N.P.D. ° ′	l.f.p.	Mag.
April 21	13 15 50	Paris	14 9 57·83	9·069	102 18 37·7	0·889	12·0
22	11 6 30	Marseilles (*b*)	14 9 10·95	9·042	102 16 46·4	0·864	11·5
22	11 24 34	Paris	14 9 10·00	8·832	102 16 41·3	0·891	
24	10 31 36	„	14 7 29·39	9·153	102 12 0·9	0·888	
25	9 41 59	Marseilles (*c*)	14 6 39·84	9·372	102 8 59·6	0·853	11·5
28	11 53 31	Paris	14 4 0·59	8·514	102 3 12·8	0·891	
30	12 36 8	Berlin	14 2 18·86	9·049	101 59 16·2	0·900	12·0

Minor planet (163) was discovered by M. Perrotin at Toulouse on April 26. Magnitude the twelfth.

1876.	Mean Time. h m s		Observed R.A. h m s	l.f.p.	Observed N.P.D. ° ′ ″	l.f.p.	Mag.
April 26		Toulouse	14 11 48		96 24		12·0
27	8 43 10	Marseilles (*d*)	14 10 54·38	9·496	96 19 13·9	0·816	12·0
28	10 9 11	Paris	14 9 54·67	9·189	96 13 16·6	0·860	
29	13 49 9	Berlin	14 8 51·66	9·299	96 7 3	0·874	
30	14 33 48	„	14 7 54·90	9·417	96 1 26·3	0·868	

M. Stéphan has also forwarded to the Society the mean positions of the four comparison-stars observed at Marseilles, derived from Weisse's Bessel, first Catalogue. The observations were made by M. Borrelly:

		R.A. h m s	N.P.D. ° ′ ″
a	W.B. xiii. 402	13 25 50·61	102 1 21·9
b	W.B. xiv. 181	14 12 5·82	102 0 39·2
c	W.B. xiv. 49	14 5 9·27	102 0 2·9
d	W.B. xiv. 186	14 12 9·89	96 26 15·8

Kidbrooke, Blackheath,
*d*1876, *May* 6.

Supplementary List of Wide Double Stars taken for the most part from Smyth's Celestial Cycle, and not included in other Catalogues. By M. Camille Flammarion.

(*Communicated by the Rev. R. Main.*)

Cat. H.	S. C. C.		
1090	121	η Eridani	
1569	159	γ Tauri	
2072	200	γ Orionis	
2124	208	β Leporis	
2152	213	α Leporis	
Cat. H.	S. C. C.		
2584	243	μ Geminorum	(If the distance = 80^s in time, and not 80″)
2724	254	γ Geminorum	(If the distance = 76^s in time, and not 79″)
3009	278	δ Canis Majoris	
3162	287	η Canis Majoris	(Is there not a star at 90″?)
3786	327	δ Hydræ	
3806	333	ϵ Cancri	
4251	366	ψ Leonis	
5480	469	ϵ Virginis	
5631	485	79 Virginis	
6636	563	δ Ophiuchi	
6730	578	β Herculis	
6928	601	η Ophiuchi	
7631	668	σ Sagittarii	
8178	719	Piazzi xxix. 295	
10129	840	ι Piscium	

Near Approach of 47 Geminorum, April 1.

By the Rev. S. J. Johnson.

Predicted as an occultation for 26 min. at Greenwich. Here, lat. 50° 48′ 45″, long. 14^m 34^s W., the star escaped being occulted. At the nearest appulse 7^h 46^m it was distant 25″ by estimation from the Moon's bright limb. On passing close by the terminator, where there were several bright spots in the dark part of the Moon, it conveyed to the eye the impression of being an additional lunar peak caught by the Sun's rays. Another star, about $\frac{1}{2}$-mag. lower, probably Σ 1037, disappeared behind the dark limb at 7^h 42^m·5. Sky cloudless.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVI. *June* 9, 1876. No. 8.

WILLIAM HUGGINS, Esq., F.R.S., President, in the Chair.

Andrew Ainslie Common, Esq., 37 Eaton Rise, Ealing; and James Love, Esq., Talbot Lodge, Bickerton Road, Upper Holloway,

were balloted for and duly elected Fellows of the Society.

Visibility of Mercury—and of Venus in Sunshine.

By William F. Denning, Esq., F.M.S.

(*Communicated by the Rev. R. Main, M.A., F.R.S.*)

The favourable east elongation of *Mercury* in May allowed him to be seen here with the naked eye on thirteen evenings; in fact, his detection between the 5th and 28th was merely a question of weather; he was, within these dates, visible every night on which the sky was clear enough. In the early part of the month (7th, 8th, and 9th) he looked brighter than a 1st mag. star on the horizon, being much plainer than *Mars* (about 13° E.), and comparing favourably in point of lustre with *a Aurigæ*. On the 13th the planet was first seen at $8^h\ 20^m$, and remained in view until $9^h\ 40^m$, which gives a duration of visibility of $1^h\ 20^m$, and this was a fair average period for a clear night between about the 10th and 20th. On the 16th the planet was first glimpsed at $8^h\ 35^m$, and on the 18th (sky partly cloudy) at $8^h\ 41^m$, continuing visible till near setting, though on these dates he had become much fainter than on the 7th, 8th, and 9th. On the 19th I watched the planet from $8^h\ 32^m$ to $9^h\ 55^m$ ($1^h\ 23^m$), but his appearance was feeble, especially during the latter part, and certainly less than 2nd mag. On the 21st (day of extreme elong.) the air was very clear in WNW., and the

planet seen at $8^h\ 55^m$, but very faintly; his light had evidently gone on decreasing rapidly since the earlier observations. Cloudy weather here supervened. On the 28th the sky was quite clear after sunset. I saw *Mercury* in the finder of my 10½-in. reflector at $8^h\ 52^m$, and could just glimpse the planet with naked eye at $9^h\ 20^m$, but it was one of the faintest objects I have ever seen, and smaller than a 3rd mag., which I could have found more easily in the same place. I saw β *Geminorum* (near *Venus*) as early as $8^h\ 35^m$. The planet set $1^h\ 50^m$ after the Sun on this date, and for some days afterwards continued well situated as regards elongation, but was totally beyond reach of the naked eye; and the actual decrease in brilliancy between the 7th and 28th must have amounted to about 3·5 mag. The stronger twilight prevailing during the latter part of the elongation partly accounts for his extreme feebleness then, and the difference of phase (from gibbous to a crescent) had a good deal to do with it, though the semi-diameter had increased from 2″·9 on the 5th to 4″·4 on the 25th. The loss of phase, however, was not nearly compensated for by increase of size; and this is pointed out in Lardner and Dunkins' "Handbook," in which it is stated of *Mercury* that "it is brightest at a less [than max.] elongation, even though it moves to a greater distance from the earth, since it gains more by the increase of its phase than it loses by increased distance and diminished elongation." This refers to the planet when nearing superior conjunction at W. elongation, but it is also true, conversely, of the E. elongation; and it would appear, therefore, that he is most favourably visible as a naked-eye object a few mornings *after* max. elong. W., and a few evenings *before* max. elong. E. This fact has been strongly marked in previous years, notably in February 1868, when he appeared to rival *Jupiter* on several nights preceding extreme elongation, and on the evenings of May 31, June 1, 2, 3, and 4, 1875, the planet was seen as a conspicuous object though the maximum elongation was not attained until June 10. This may account for the many futile efforts to see *Mercury*. Elongation is a necessary element in his detection, but a crescented phase may so enfeeble his light as to render him utterly beyond reach, as on May 29th.

Venus has been quite conspicuous as a naked-eye object in sunshine during the last three months. The first time I glimpsed the planet (during the present evening apparition) was on February 22, at $4^h\ 45^m$. On February 23 she was seen at $1^h\ 45^m$, and on February 28 precisely at noon. On the latter date I watched the planet for about 30^m; she was somewhat faint, though I found her readily enough a few degrees west of the crescent of the new moon. She was plainer on March 4 at $1^h\ 40^m$. The planet must be rarely seen at noon so early as February 28, as the circumstances are unfavourable. On the occasion now referred to the semi-diameter was scarcely 7″, and altitude 35°. The fact of her visibility at such a time proves with what ease she may be seen under better conditions.

During the present month her high altitude has rendered her surprisingly bright as a daylight object, and in strong contrast with her feebleness when I saw her at the end of February.

Bristol, May 30, 1876.

On the Atmosphere of Venus.

By E. Neison, Esq.

In the *Astronomische Nachrichten* for 1849 (No. 679, vol. xxix. p. 107) are published some observations, by Clausen and Mädler, of the prolongation of the cusps of *Venus* when the planet was near conjunction, and which showed that the Sun's rays underwent a considerable refraction from the atmosphere of the planet. The extent of the prolongation of the cusps of *Venus* was measured with the great Dorpat telescope, and from these measures the amount of the horizontal refraction exerted by the atmosphere of *Venus* was ascertained by means of formula which was given.

This formula was as follows:—

Let V = the angular distance between the centres of the Sun and *Venus*;

x = the prolongation of the cusps of the planet;

S = the semi-diameter of the Sun;

ϕ_1 = the radius-vector of *Venus*.

Then the horizontal refraction ζ_o of the atmosphere of *Venus* was found from the equation

$$\zeta_o = \frac{1}{2}\left(\psi - \frac{S}{\phi_1}\right),$$

where

$$\sin \psi = \sin V \sin x.$$

By this method Mädler found the horizontal refraction of the atmosphere of *Venus* to be 43″·7, or about $\frac{1}{6}$th greater than the Earth's. This result Mädler subsequently sent to the Astronomer Royal, who communicated an account of the same to the Royal Astronomical Society, and it appeared, in due course, in the *Monthly Notices* (vol. xviii. p. 320).

Lately this formula has been employed by Professor C. S. Lyman, of Sheffield, United States, to reduce similar measures of the prolongation of the cusps of *Venus*, made with a fine 9-in. refractor during 1866 and 1874. By its means Professor Lyman found from his observations 45″·3 and 44″·5 for the horizontal refraction of the atmosphere of *Venus*.

A note by Mr. R. A. Proctor, in the *Astronomical Register* (October 1875), induced me, as soon as I had the leisure, to

examine this formula of Mädler's, when it was at once apparent that as it had been employed by Mädler and Lyman it was defective. Instead of the angle V or the angular distance between the centres of the Sun and *Venus* as seen from the Earth which they had used, they should have employed the supplement of the angle between the Sun and Earth as seen from *Venus*. In consequence of this error the value which they have deduced from their observations for the horizontal refraction of the atmosphere of *Venus* is incorrect.

Retaining the notation above, and for additional accuracy putting

S′ = the semi-diameter of *Venus*,

ϕ = the radius-vector of the Earth,

then the proper equation for finding the horizontal refraction is

$$\zeta_0 = \frac{\phi}{2\phi_1}\{(V + S' \sin x) \sin x - S\}.$$

The above expression is easily found, for if in the triangle formed by the Sun, Earth, and extremity of the prolongation of the cusp of *Venus*, we put θ for the angle at the Earth, and if ψ represents the apparent deflection of the solar rays, or the supplement of the angle at *Venus*, then

$$\frac{\sin \psi}{\phi} = \frac{\sin \theta}{\phi_1}.$$

It is easy to see that from this definition we have

$$\theta = V + S' \sin x,$$

and

$$\psi \sin x = 2\zeta_1 + \frac{\phi}{\phi_1} S.$$

It only remains to replace the ratio of the sines by the ratio of the angles, which is permissible, the angles being very small, and the above equation results at once.

Applying this formula to the observations given by Mädler in the *Astronomische Nachrichten* and the values for the horizontal refraction, which results are

60″·12, 54″·33, 47″·70, 49″·72, 49″·97, 58″·73, and 60″·44;

the mean value is 54″·43, or 54″·26″, and a probable error of 1″·38.

The four observations by Lyman, made during 1874, are probably far superior in accuracy to Mädler's, and were made under better conditions. They are each the result of a number of repeated measures, and give for the horizontal refraction the values

56″·34, 51″·54, 54″·63, and 51″·49;

the mean value is 53′·50 or 53′·30″, agreeing closely with the result obtained by Mädler.

The mean between these two results is 54′·65 or 54′·39″, and this value is probably within one minute of arc of the true value of the horizontal refraction of the atmosphere of *Venus*. The details of the measures made by Lyman in 1866 not having been published, it has not been possible to reduce these; considering, however, the nature of the error in the formula by which they were reduced by Lyman, the mean of these observations cannot differ much from the value 54′·7, a result well in accord with the other two series.

It appears, therefore, that the value found from their observations by Mädler and Lyman, for the horizontal refraction of the atmosphere of *Venus*, must be increased from 44′·5 to 54′·65.

From the value of the horizontal refraction of the atmosphere it is easy to deduce the surface density of the same. The method of effecting this has been already given (*Monthly Notices*, vol. xxxv., p. 331). Supposing the surface density equal to that of the Earth's, the horizontal refraction which it would exert could not differ much from 28′·53″. Consequently, the value found above for the amount of the horizontal refraction shows that the density at the surface of *Venus* of its atmosphere cannot differ much from being 1·892 times that of the Earth's, or nearly twice as dense. This is entirely in accord with the phenomenon presented by the planet, which indicates the presence of an atmosphere materially denser than that of the Earth's.

Repeated observations have shown that when *Venus* is near the Sun the entire planet can be seen as a dark circular disk. This appearance may arise either from the planet being seen projected against a bright background—such as, for example, the solar corona—or else from being surrounded by a faint ring of light due to the refraction of the solar rays by the atmosphere. Reversing the formulæ already given, it is easily found that the maximum distance from the Sun at which the planet's atmosphere has power to refract the solar rays so as to form a complete ring of light around the planet is

$$V = 2\frac{\phi'}{\phi}\zeta_0 + (S - S').$$

The greatest value this can have is 1° 37′. But the ring of light would be sufficiently near completeness at a distance of even 2° to present the same appearance. From the natural tendency of the eye to supply the missing portion of a faint ring of light, it is very probable that, except in very careful observations, even at a distance of 5° from the Sun, the prolongation of the cusps of the planet (about 20°) would be sufficient to make it present the appearance of a circular dark disk on a brighter background.

Observations of Venus. By Capt. W. Noble.

Having been in the habit, for many years past, of observing *Venus* in nearly every part of her orbit, with a very considerable range of powers, and under the most varying conditions of atmosphere and illumination; I was very much struck by Mr. Brett's announcement, at our last meeting, that he had detected unmistakable specular reflection from the body of that planet. Believing that, had this phenomenon been anything like so apparent as his very artistic drawing represented it to be, I *must* have seen it, I yet so far mistrusted my own considerable experience, as to admit the possibility that Mr. Brett's exquisitely-trained eye might have detected an appearance which had been previously overlooked by others less specially employed in regarding form, light, and shade, with a view to their reproduction. Since the 12th of last May, therefore, I have availed myself of every favourable opportunity to investigate this question of alleged specular reflection from *Venus*; but, I may as well say at once, with the most absolutely negative results.

My first step was to examine the planet, which I did in daylight, twilight, and at dusk, with various powers from 84 to 394, to see whether I could detect any indications of specular reflection by ordinary telescopic vision. I could discover none whatever; the whole of the light in the neighbourhood of the illuminated limb was as homogeneous as it possibly could be. I then, using a power of 255, interposed a graduated shade of dark glass; traversing it, with the utmost slowness, before the eye-lens of my eye-piece until the planet was rendered invisible. Under these circumstances the first part to fade away was (as might, *à priori*, have been expected) that in the neighbourhood of the terminator: and the effect presented was, of course, that of the material reduction of the breadth of the crescent. Then the actual cusps vanished; and, finally, the central part of the illuminated periphery of *Venus went out altogether*; not the slightest sign, trace, or indication of specular reflection—or of one part being in the smallest degree brighter than another—being visible. With a very dark green eye-glass too, of uniform tint, which extinguished the cusps, the light of the limb remained absolutely without difference of brightness of any description.

In addition to these observations, made and repeated on numerous occasions with my 4·2-in. Ross achromatic, I have examined the planet with the beautiful 6·25-in. Browning—with reflector belonging to my friend Mr. H. J. Slack, F.G.S., &c., employing his own wedge of dark glass for cutting off the light of the planet—and with precisely the same result. I can then only come to the conclusion that *Venus* does *not* exhibit anything whatever in the nature of specular reflection; and that its apparition, in Mr. Brett's case, must have had its origin either in his instrument or in his eye.

It may not be uninteresting to add that, while my experiments were in progress, I discovered that, by waiting until the evening was dark enough, I could, with a power of 154 (or, in fact, any other—but this is the one with which I make the discovery) distinctly make a quasi-phosphorescent body of *Venus* out of the blue light resulting from the very slight over-correction of my object-glass. This "dark limb" was quite startling in its apparent objectivity; but, as pointed out by Mr. Green in his oral address at our April meeting, it vanished completely on hiding the illuminated crescent.

Forest Lodge, Maresfield,
1876, *May* 27.

Photometric Experiments upon the Light of Venus.

By John I. Plummer, Esq.

The planets *Venus* and *Jupiter*, it is well known, are frequently sufficiently bright when favourably situated to cast a well-defined shadow, but hitherto advantage has not been taken of this circumstance to determine the relative intensities of their light to that of the Full Moon, nor to compare it with any standard terrestrial source of light. The following experiments and observations have been attempted with a twofold purpose: First, to ascertain whether this troublesome problem might not be attacked successfully from a new point of view, so that estimates of relative brilliancy may be made in the simple manner I have to describe as reliable as those made with costly photometers; and secondly, to determine by observation alone the variations in the amount of light reflected from *Venus* towards the Earth at its various phases. As photometric comparisons are known to be liable to much error, and are necessarily affected by the peculiarities of vision of the observer, it may be thought desirable that they should be made not only in as many different ways, but by as many different persons as possible. This is my excuse for attempting a problem various portions of which have received the attention of Herschel, Bond, Zöllner, and still more particularly of Seidel. Moreover, *Venus*, owing to its close proximity to the Sun, has had less attention paid to it than any other, while its brightness is such that it is most suitable for the direct comparison of shadows.

The plan that I have adopted has been to compare the light of the planet with that of a standard sperm candle burning 120 grains of wax per hour, and to vary the distance of this until the shadow it casts upon a screen of white paper has an equal degree of intensity to that given by the planet. It being found impossible to get the two shadows upon the same screen, separate screens were arranged for each, and brought as near to each other as possible. The arrangement was therefore a modification of Rumford's photometer. The objects of which the shadows were

observed were two equal cylindrical steel wires of $\frac{1}{16}$-inch diameter, placed in a dark room nine feet in front their respective screens; but the judgment was further assisted by noting also the shadows of the wooden laths to which the wires were attached, and of which the thickness was about $\frac{1}{2}$-inch. These conditions were preserved throughout the whole of the observations. To protect the candle from wind, it being necessarily placed in the open air, it was fixed within a lantern, which was itself enclosed, except upon one side, in a rough wooden box painted a dull black. These precautions are believed to have been sufficient for their purpose.

That in dealing with the light of *Venus* and the shadow which it is capable of throwing upon a screen properly situated we have not to deal with a faint or doubtful trace, the following facts may be noted: Thus on March 29, the Moon being four days old and within 12° of Venus, the light from each was received upon the same screen, and the shadow from *Venus*-light was still conspicuously visible. Upon the same evening *Sirius*, though having a light-intensity about $\frac{1}{5}$th that of *Venus*, was also observed to cast an appreciable shadow, the direct light of the Moon being, of course, excluded from the room in this case. That *Sirius* is sufficiently bright to produce a definite illumination upon a screen has not, I believe, been previously observed; and I may mention here that there would seem to be no difficulty in determining by this method the relative brilliancy of those planets which exceed *Sirius* in brightness; and I have been deterred from at present extending this investigation to *Jupiter* and *Mars* only by the impossibility of obtaining a sufficient range through which to vary the distance of the candle. On April 26, the light of *Venus* and of the young Moon were observed to fall upon a plaster wall in the open air, and the shadows of neighbouring buildings referable to each of these bodies were distinctly observable at the same time. For obvious reasons, no observations have been taken when the Moon was near full; and only on one occasion an observation was taken when the Moon was above the horizon; but there would not have been the least difficulty in continuing the observations under all circumstances. The following comparisons have been made:—

1876.	h	m	Observed Distance of Candle. Feet.	Calculated Altitude of ☽ ° ′	Log C = Log $\frac{\text{☽ corrd. for extinct.}}{\text{Candle at 1 ft. dist.}}$	Log C $\frac{r^2\Delta^2}{r_0^2\Delta_0^2}$	Phase of ☿ °
Mar. 20	8	40	290·65	12 42	5·1715	5·2198	114·9
,, 24	8	44	334·5	13 31	5·0314	5·0561	113·1
Apr. 14	8	52	286·25	19 41	5·0636	4·9458	102·5
,, 21	8	59	263·75	20 20	5·1269	4·9537	98·9
,, 23	9	6	265·0	19 38	5·1322	4·9423	97·9
,, 26	9	22	306·0	17 50	[5·0311]	[4·8153]	96·4
May 11	9	46	275·42	15 30	5·1605	4·8013	84·1
[illegible]13	10	26	314·19	6 37	[5·3623]	[4·9817]	83·2

Upon all these occasions the sky has been brilliantly clear and the equality of the shadows has been considered satisfactory by at least two persons. The probable error of a single determination is believed not to exceed 6 feet. The correction for extinction of light by the atmosphere has been obtained from Seidel's Table, but in order to be as independent as possible of arbitrary constants those corrections only have been applied to reduce the results to an uniform altitude of 18°, which is nearly the mean of the observations. Rejecting the results obtained on April 26 and May 13 (the first because the Moon was shining at the time of comparison, and the second because *Venus* was very low and appears to be over-corrected for extinction), and taking the means of results on March 20, 24, and April 14, 21, 23, we obtain the ratios $\frac{1}{78152{\cdot}5}$, $\frac{1}{77861{\cdot}0}$, $\frac{1}{69101{\cdot}9}$, to express the relation of *Venus* light to that of the candle at the distance of one foot when the illuminated portion of the planet is 114°, 100°, and 84° respectively, showing that *Venus* approaches its point of maximum brilliancy on June 6 very gradually indeed. Or taking the mean of the six comparisons, we have the light of *Venus* when 101°·9 of its illuminated disk is turned towards us and its altitude is 18°, equivalent to that of a sperm candle at the distance of 276·3 feet and its intensity equal to $\frac{1}{276{\cdot}3^2} = \frac{1}{76343}$ part of that of the candle at the distance one foot.

The next step was to reduce the values obtained (Column IV.) to some assumed distance of *Venus* from the Sun and Earth, and to exhibit the comparison of light intensities affected only by the changing phase. The distances assumed for this purpose r_0 and Δ_0 are 0·7184 and 1·0000 respectively, and the results are given in column V. I have then compared, by means of a graphical construction (see Diagram), the curve that best satisfies the observations with those yielded by both Lambert's and Euler's formulæ, taking the intensity of light when $v = 84°{\cdot}1$ as unity; and, although the interval of time over which the observations extend is too limited to admit of a definite conclusion being drawn, they appear to indicate that *Venus*, like the Moon, increases in brightness as it approaches the full phase much more rapidly than can be accounted for upon theoretical considerations only. It will be seen also that Lambert's formula much more nearly satisfies the observations than does Euler's. Some further evidence on this point may possibly be obtained after the inferior conjunction, when the twilight being of shorter duration will interfere less with the observations.

To obtain results independent of any terrestrial source of light it was necessary to compare the sperm candle that had been employed in the observations of *Venus* with the Full Moon, and to do this it was found more convenient to have recourse to the principle of Bunsen's photometer. The comparisons were effected upon April 8 and May 7, and they have

been treated in precisely the same way as those of *Venus*, except that in addition a small correction has been applied to reduce the light of the Moon on May 7 to the full phase. No such correction is needed on April 8. Euler's formula $\left(\theta = \sin^2 \frac{1}{2} v\right)$ has been used for this purpose. The results are tolerably accordant, giving the light of the Full Moon at the altitude of 18°, its semi-diameter being 934″·67, equivalent to that of the candle at distances of 8ft·888 and 8ft·641, or giving weight, according to the number of comparisons on each evening, of 8ft·722. Combining this value with that of the mean of the observations of *Venus*, we have,

$$\frac{\text{Actual Light of } Venus\ (v = 101°{\cdot}9)}{\text{Mean Full Moon}} = \frac{1}{1004}.$$

A more accurate mode of treatment would probably be to reduce each observation separately to some standard phase, and take the mean of the results. Assuming, as Seidel has done, that *Venus* attains its greatest brilliancy when $v = 76°{\cdot}13'{\cdot}5$, $\Delta = 0{\cdot}53944$, and $r = 0{\cdot}7233$, and using Lambert's formula

$$\left(\theta = \frac{\sin v - v \cos v}{\sin v_0 - v_0 \cos v_0}\right)$$

to effect the reduction we obtain

$$\frac{Venus \text{ at greatest brilliancy (alt. } 18°)}{\text{Standard sperm candle at 1 foot dist.}} = \frac{1}{60813{\cdot}8} = \frac{1}{246{\cdot}6^2}.$$

If the suspicion to which I have alluded be correct, that Lambert's formula is not strictly applicable to *Venus*, this result will, of course, be slightly in excess of the truth. Again, introducing the above-determined value of the mean Full Moon, we have

$$\frac{Venus \text{ at greatest brilliancy}}{\text{Mean Full Moon}} = \frac{1}{799{\cdot}5}.$$

I have not been able to find any previous comparison of *Venus* with the Full Moon with which to compare this result, except what may be inferred from Bond's observations (*Memoirs of the American Academy*, vol. viii.), which give the light of *Jupiter* at mean opposition equal to $\frac{1}{6430}$ that of the mean Full Moon, and the ratio of the light of *Venus* at greatest brilliancy to *Jupiter* as 4·864 to 1, which differs only very slightly from Seidel's comparison of these two planets. This would yield the ratio $\frac{1}{1322}$ as comparable with my result; or, in other words, I attribute to *Venus* a brilliancy about 65 per cent. greater than

Bond has found. Since the methods employed are entirely dissimilar, and since Bond's investigation has chiefly to do with the Moon and *Jupiter*, both of which he has observed at altitudes generally much greater than those at which the observation of *Venus* is possible, this discordance does not prove much.

Orwell Park Observatory, near Ipswich,
1876, June 1.

On the Proper Motion of Bright Spots on Jupiter.

By John Brett, Esq.

There have recently appeared upon the disk of *Jupiter* two bright spots, of such distinctness and isolation as peculiarly adapt them for measurement, with a view to determine either the rotation of the planet, or their own proper motion.

I beg leave to lay before the Society the record of four observations of these spots, forming a series extending over a period of 286 hours 20 minutes of mean time, and to ask whether they afford evidence of proper motion, or whether, on the other hand, they tend to cast any doubt on the accepted rotation of the planet. There were several peculiarities about these two spots which seem to me to give them an eminent claim to attention. They occurred very near to the equator, and were very well defined, and free from entanglement with other markings: an advantage which they have maintained with singular uniformity throughout the period mentioned; but the special peculiarity to which attention is asked is, that during an interval of five days they remained in the same relative position, without any variation whatever.

Their stability in respect of latitude during those five days is undoubted; but the question is, whether or not they were equally stable in longitude. This remark only applies to the first five days of the series, because at the end of twelve days a certain deviation was obvious, as may be seen from the drawings which accompany this paper.

The drawings are fairly accurate, and I have no excuse to offer for them if they are not so. It is more easy for a practised draughtsman to detect differences of position or extension by the unassisted eye than by the micrometer-wire; and this is especially true of such delicate phenomena as planetary markings.

The first observation was made on May 23rd, 1876, at $11^h\ 30^m$ G.M.T., and is recorded by the drawing marked A.

The second observation, May 28, 1876, at $10^h\ 30^m$ G.M.T., by the drawing B.

The distance between the two spots occupies about 42° of Jovian longitude, or about 33,000 miles. Their diameter is nearly

They appear to have gained on the assumed rotation during this interval at the rate of $7^m\ 14^s$ per revolution.

Between the drawings C and D, the last of the series, there is an interval of 20 minutes of time, during which the spots passed over about 15° of longitude, proving that they were certainly not losing on the rotation.

Taking the series of observations together, the conclusion I derive from them is that the period of the spots is less than the rotation of the planet, and that their least proper motion is 165 miles per hour.

It will not be denied that this, if established, is a very remarkable circumstance.

The only alternative inference, viz., that there is an error in the assumed rotation, is negatived by the consideration that the rate of the spots is not uniform. It must, however, be remembered that the rotation is derived from observations of some such spots.

The proper motion theory is not without its difficulties. It must not be forgotten that these phenomena which are described as bright spots are bodies of approximately globular form. The fact of their casting shadows was discussed before this Society two years ago, and the existence of those shadows has since been confirmed in a paper presented to the French Academy last November by M. Faye.

The shadows of the two spots under consideration are sufficiently pronounced to indicate a globular form, and to afford evidence that light can penetrate the planet to the depth of more than 6,000 miles; but that the material of which it consists is sufficiently limpid at that depth to allow bodies nearly as large as the *Earth* to swim about in it seems at first sight rather startling, not to mention the question what inducement or excuse they could have for advancing in the direction of the planet's rotation.

The fact that they are wholly immersed in the semi-transparent material of the planet is indisputable, since they gradually disappear as they approach the limb, and in no case have been seen to protrude beyond it.

I cannot imagine any subject in physical astronomy on which diligent observation is more required, or one on which good observing faculties may be more fruitfully employed. I may mention that a 9-inch reflector shows these phenomena in a very satisfactory manner, but they *can* be seen with a 4-inch refractor. As the planet approaches quadrature the shadows ought to become more obvious, so that we may hope to hear more of them before the next session of the Society.

June 9, 1876.

maximum positive error moving forward to about 0° and that of negative error to 180° in the course of a few years' observations.

It was now evident that, in the investigation of this inequality, its period might, during any one year, be regarded as the same with that of the Moon's mean anomaly, and that thus, during this interval, it would be identified with the correction to the eccentricity and perigee. Owing, however, to the want of exact coincidence of period, the apparent errors of eccentricity and perigee would be different from year to year—these elements would, in fact, appear to be affected with an inequality of long period.

In order to make the investigation more complete I also determined the corresponding corrections for the years 1847 to 1858, for which the residual errors of Hansen's Tables are given in the Greenwich observations for 1859. The resulting corrections and the mode in which the new term is brought out are shown in the following table. The residual errors of Moon's longitude during each term of about a year were supposed to be represented in the form

$$\Delta \delta l + h \sin g + k \cos g,$$

g being the mean anomaly, and h and k the coefficients to be determined from observation, on which depends the correction to eccentricity and perigee. Their values in terms of these last are—

$$h = -2\delta e$$
$$k = 2e\delta\pi.$$

The values of h and k, as they result immediately from observations, are shown in the second and third columns of the following table. Their periodicity is obvious. To make its law more evident, we find by a preliminary treatment that the constant portions of these quantities are approximately—

$$\text{const. of } h = h_0 = +0''.50,$$
$$\text{const. of } k = k = +0''.10.$$

Subtracting these portions, we obtain the values of the purely periodic portions, which we call h' and k', and which we present in the next two columns. We now see from these columns that in addition to h' and k' being separately periodic, they have each about the same period, and if one is represented by a cosine, the other will be nearly represented by the sine of the same angle. Let us then determine α and N from the equations

$$\alpha \sin N = -h',$$
$$\alpha \cos N = k'.$$

The values of α and of N thus deduced are shown in the two

following columns. The regular progression of the angl too striking to be overlooked, extending as it does throu interval of 27 years. We wish to see how it may be repre by a quantity increasing uniformly with the time. W remark that the greater the value of α the more accurate it be fixed by the observations. On this principle, we ass N the weight in the column next following. The angle best represents it, determined by least squares, is given column $\mu + nt$. I afterwards concluded that too great weig been given to the older observations, and finally adopted, most probable value of N,

$$N = 163°.2 + 21°.6\ (t - 1868.5),$$

the residuals from which are given in the last column. mean values of α are—

from the old series, $\alpha = 1''.66$;

from the new series, $\alpha = 1''.55$.

The effect of the accidental errors of observation is to in the value of α. I therefore consider that we may put—

$$\alpha = 1''.50.$$

[It may be remarked that the values of α and N d rigorously by least squares from the second series of observ above are—

$$\alpha = 1''.52,$$
$$N = 161°.2 + 22°.8\ (t - 1868.5)].$$

The table referred to is :

Mean Date.	h	k	h'	k'	α	N	Wt.	$\mu + nt$	ΔN
	"	"	"	"	"	°		°	°
1847·8	−0·08	+0·55	−0·58	+0·45	0·74	52	1	94	+ 4
48·9	−0·55	−1·38	−1·05	−1·48	1·82	145	3	118	− 2
50·1	−0·20	−1·91	−0·70	−2·01	2·13	161	3	141	− 2
51·2	−0·32	−1·92	−0·82	−2·02	2·18	158	3	165	+
52·4	+0·26	−2·45	−0·24	−2·55	2·56	175	4	189	+ 1
53·5	+1·10	−1·88	+0·60	−1·98	2·07	197	3	212	+ 1
54·6	+1·45	−1·40	+0·95	−1·50	1·77	212	3	236	+ 2
55·8	+0·77	+0·31	+0·27	+0·21	0·34	308	½	260	− 4
56·9	+1·76	+1·82	+1·26	+1·72	2·13	328	½	284	− 4
1858·1	−0·17	+0·66	−0·67	+0·56	0·88	50	1	307	−10

Mean Date.	h	k	h'	k'	a	N	Wt.	$\mu+nt$	ΔN	Δ'N
	"	"	"	"	"	°		°	°	°
1862·5	+0·04	+1·23	−0·46	+1·13	1·22	22	3	40	+ 18	+ 12
63·5	−0·64	+1·78	−1·14	+1·68	2·03	34	5	61	+ 27	+ 21
64·5	−1·07	+1·09	−1·57	+0·99	1·85	58	5	81	+ 23	+ 19
65·5	−1·03	−0·15	−1·53	−0·25	1·55	99	4	102	+ 3	− 1
66·5	−0·47	+0·10	−0·97	0·00	0·97	90	2	123	+ 33	+ 30
67·5	−1·93	−0·36	−1·43	−0·46	1·50	108	4	144	+ 36	+ 34
68·5	+0·34	−1·46	−0·16	−1·56	1·57	174	4	165	− 9	− 11
69·5	+1·67	−1·56	+1·17	−1·66	2·03	215	5	185	− 30	− 30
70·5	+1·48	−1·14	+0·98	−1·24	1·58	218	5	206	− 12	− 12
71·5	+1·65	−0·36	+1·15	−0·46	1·24	248	3	227	− 21	− 20
72·5	+2·15	−0·12	+1·65	−0·22	1·66	262	4	248	− 14	− 12
73·5	+1·91	+0·16	+1·41	+0·06	1·41	272	4	269	− 3	− 1
1874·5	+1·92	+0·60	+1·42	+0·50	1·50	289	4	289	0	+ 4

The corrections to the Moon's longitude arising from this term is—

$$\begin{aligned} \delta v &= -h' \sin g - k' \cos v \\ &= -1''{\cdot}50 \,(\sin \mathrm{N} \sin g - \cos \mathrm{N} \cos g) \\ &= -1''{\cdot}50 \sin (g + \mathrm{N} - 90°), \end{aligned}$$

which is the hitherto unnoticed apparent inequality of the Moon's longitude.

The period of N is $16\frac{2}{3}$ years, with a probable error of about half a year, and a possible error of a year or more. The corresponding period of $\mathrm{N}+g$, or of the inequality in longitude, is—

$$27{\cdot}4304 \text{ days} \pm 0^{d}{\cdot}0040.$$

There is a large preponderance of probabilities against the real period being either less than $27^{d}.42$ or more than $27^{d}.44$. No known term in the Moon's longitude falls between these limits. The Moon's sidereal period is $27^{d}.32$, and her anomalistic period is $27^{d}.55$, so that the new term falls half-way between these two.

The non-accordance of this period with that of any term heretofore sought for is the reason why this term has not before been noticed. A term of unknown period would not be remarked unless its magnitude was such as to visibly affect the individual comparisons of theory with observations; and Hansen's Tables, as corrected, are the first ones of which the residual errors are so small that a term of $1''{\cdot}5$ would be remarked in the comparison with observations.

On the Determination of the Distances of a Comet from the Earth from Three Observations. By Dr. F. W. Berg.

Let us designate by $K_{,,}$ the longitude of the ascending node, and by $T_{,,}$ the inclination to the ecliptic, of a great circle passing through the first and second observed places of the heavenly body, which may be given by means of $\alpha, \alpha', \beta, \beta'$, and we have—

$$\tan\beta = \sin(\alpha - K_{,,}) \tan T_{,,},$$
$$\tan\beta' = \sin(\alpha' - K_{,,}) \tan T_{,,};$$

and therefore, for the great circle passing through the second and third places, and for the great circle passing through the first and third places, we obtain—

$$\tan\beta' = \sin(\alpha' - K\ ) \tan T,$$
$$\tan\beta'' = \sin(\alpha'' - K\ ) \tan T,$$
$$\tan\beta = \sin(\alpha - K_{,}) \tan T_{,},$$
$$\tan\beta'' = \sin(\alpha'' - K_{,,}) \tan T_{,,}.$$

Substituting these abbreviations in the Gaussian expressions (O.1.2.), (o.O.2), etc. (conf. *Theoria Motus*, art. 113), we find—

$$(O.1.2) = \sin(\alpha'' - \alpha').M, \quad (I.1.2) = \sin(\alpha'' - \alpha').M', \quad (II.1.2) = \sin(\alpha'' - \alpha').M'',$$
$$(o.O.2) = \sin(\alpha - \alpha'').M_{,}, \quad (o.I.2) = \sin(\alpha - \alpha'').M_{,}', \quad (o.II.2) = \sin(\alpha - \alpha'').M_{,}'',$$
$$(o.1.O) = \sin(\alpha' - \alpha\ ).M_{,,}, \quad (o.1.I) = \sin(\alpha' - \alpha\ ).M_{,,}', \quad (o.1.II) = \sin(\alpha' - \alpha\ ).M_{,,}'',$$

if we put—

$$M = \tan B + \sin(K - L) \tan T,$$
$$M_{,} = \tan B + \sin(K_{,} - L) \tan T_{,},$$
$$M_{,,} = \tan B + \sin(K_{,,} - L) \tan T_{,,};$$

and these expressions will give $M', M_{,}', M_{,,}', M'', M_{,}'', M_{,,}''$, if we change B and L into B′ L′ and B″ L″.

Therefore, we obtain from the equations (9), (10), (11) (conf. *Theoria Motus*, art. 114)—

(A)
$$o = n\ (O.1.2)\ \delta + \sin(\alpha'' - \alpha').P,$$
$$o = n'\ (O.1.2)\ \delta' + \sin(\alpha'' - \alpha).P_{,},$$
$$o = n''\ (O.1.2)\ \delta'' + \sin(\alpha' - \alpha).P_{,,},$$

if we put

$$P = n M D - n' M' D' + n'' M'' D'',$$
$$P_{,} = n M_{,} D - n' M_{,}' D' + n'' M_{,}'' D'',$$
$$P_{,,} = n M_{,,} D - n' M_{,,}' D' + n'' M_{,,}'' D''.$$

For the case where the great circle through the first and third observed places of the body passes also through the second place, we have

$$(O.1.2) = o,$$

and

$$T = T_{,} = T_{,,}, \qquad K = K_{,} = K_{,,};$$

and, consequently,

$$M = M_{,} = M_{,,},$$
$$M' = M_{,}' = M_{,,}',$$
$$M'' = M_{,}'' = M_{,,}'',$$

and the equations (A) give only the relation

$$P = P_{,} = P_{,,} = 0,$$

whence

(B) $$n M D - n' M' D' + n'' M'' D'' = 0.$$

It is to be here remarked that the values $P\ P_{,}\ P_{,,}$ are of the third order with reference to the intervals of time.

In the formula (B) we may change n, n', n'' into N, N', N'', where N, N', N'' have the same signification for the orbit of the Earth which have n, n', n'' for the orbit of the comet.

We hence obtain

(C) $$N M D - N' M' D' + N'' M'' D'' = 0;$$

and, consequently, we obtain from (B) and (C)

$$\left(\frac{n}{n'} - \frac{N}{N'}\right) M D + \left(\frac{n''}{n'} - \frac{N''}{N'}\right) M'' D'' = 0;$$

and therefore

(D) $$n : n' : n'' = N : N' : N''.*$$

If we divide the third of the equations (A) by the first, we obtain in general:

(E) $$\frac{\delta''}{\delta} = \frac{n}{n''} \cdot \frac{\sin(\alpha' - \alpha)}{\sin(\alpha'' - \alpha')} \cdot \frac{P_{,,}}{P};$$

and, consequently, in the case in which

$$(0.1.2) = 0,$$

we obtain

(F) $$\frac{\delta''}{\delta} = \frac{n}{n''} \cdot \frac{\sin(\alpha' - \alpha)}{\sin(\alpha'' - \alpha')};$$

or, having regard to (D),

(G) $$\frac{\delta''}{\delta} = \frac{N}{N''} \cdot \frac{\sin(\alpha' - \alpha)}{\sin(\alpha'' - \alpha')}.$$

The value of the fraction $\frac{P_{,,}}{P}$ is equal to unity only when the equation $(0.1.2) = 0$ is accurately true; but if the equation $(0.1.2)$

* Compare Gauss, *Theoria Motus Corporum Cœlestium*, art. 162, and Olbers, *Abhandlung über die leichteste Methode die Bahn eines Cometes zu bestimmenm, herausg. von Encke*, Weimar, 1847, p. 80.

$=0$ is only the result of errors of observation, the value of the fraction $\frac{P_{,,}}{P}$ may be affected with an error of the order zero with reference to the intervals of time, which error may be sometimes large.*

Wilna Observatory,
April 27 (*May* 9), 1876.

Note by the Editor.—In the foregoing paper the notation is as follows:

α, geocentric longitude of Comet,
β, „ latitude,
δ, „ distance, projected on plane of Ecliptic,
L, heliocentric longitude of Earth,
B, „ latitude,
D, „ distance, projected on plane of Ecliptic,

viz., these values refer to the first observation; the corresponding accented quantities α' etc. refer to the second observation, and the doubly accented quantities α'' etc. to the third observation.

We have for the great circle passing through the second and third geocentric places of the Comet:

K, longitude of ascending node,
T, inclination,

in reference to the Ecliptic; and similarly for great circle through third and first places $K_{,}$, $T_{,}$; and for great circle through first and second places $K_{,,}$, $T_{,,}$.

The Gaussian function (0, 1, 2) denotes

$$\tan\beta \sin(\alpha''-\alpha'') + \tan\beta' \sin(\alpha-\alpha'') + \tan\beta'' \sin(\alpha'-\alpha);$$

and if herein for (α, β), (α', β'), or (α'', β''), we write (L, B) (L′, B′) or (L″, B″) the symbol 0, 1, or 2, as the case may be, is changed into O, I, or II.

Errata.

Page 306, second line from bottom, before the words "in the Dorpat," the words "*not seen*" should be inserted.

Page 307, seventeenth line from bottom, after the words "which shew" the word "*no*" should be inserted.

These errors reverse the meaning.

Page 308, fifth line from top, for *speculæ* read *specula*.

* Compare *Briefwechsel zwischen Olbers und Bessel, herausg. von Erman*, Leipzig, 1852, Band I. pp. 384 and 387.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVI. SUPPLEMENTARY NOTICE. No. 9.

Reference Catalogue of Astronomical Papers and Researches.

By E. B. Knobel, Esq.

A Catalogue of Scientific Papers, classified according to subjects, is a desideratum and a necessity to exhaustive scientific research, which I hope may be undertaken by our Public Library before many more years are allowed to pass.

I have made an attempt to supply this want, for a few branches of Stellar Astronomy, by a series of references to all books, papers, and notes relating to the following subjects:

1. Double Stars, including the Mathematical Investigation of the Orbits of Binary Systems.
2. Variable Stars.
3. Red Stars.
4. Nebulæ and Clusters.
5. Proper Motions of Stars.
6. Parallax and Distance of Stars.
7. Star Spectra.

It has been my endeavour to make the references exhaustive of astronomical literature; and though, where such an immense number of volumes have to be consulted, omissions are inevitable, I trust these will not be found very numerous.

They are derived mainly from a systematic examination of the libraries of the Royal Society and the Royal Astronomical Society, and as the first is peculiarly rich and complete in the Transactions of scientific Societies, I do not think many errors will be found in references to such works.* I have taken

* Exception, however, must be made to the large amount of scientific literature which is at present hidden in the Russian and Hungarian languages. It is a great misfortune that the titles of the majority of Memoirs and Papers printed in those languages should not be given also in *Latin*, which is a universal language for scientific men, and would be the means of bringing to their knowledge researches now entirely lost.

nothing from any index or catalogue of scientific papers, and every paper or book to which reference is made, with only one exception,* I have personally examined.

The abbreviated titles of Academies adopted are so well known as to make any explanation of them unnecessary. For simplicity I have thought it sufficient to indicate merely the number of the volume, without page, of the Memoirs of certain Societies where the papers are not numerous, or the volume is not paged throughout. On the subject of "Double Stars," every volume of the *Monthly Notices of the Royal Astronomical Society* contains one or more papers, and as the Indices to the volumes are very good, it seemed sufficient to give a general reference. But where, as on the subject of "Variable Stars," one or two volumes of the *Monthly Notices* furnished no information, then the page of every volume referred to is given.

In the *Astronomische Nachrichten* I have given simply the number without volume or page, which is the method commonly adopted in referring to this valuable publication. Should any difficulty be experienced in finding the column of the number referred to, the Indices to each volume will be found very carefully prepared and tolerably exhaustive of its contents.

All references to the *Connaissance des Temps* must be understood as applying to the "Additions."

Under the title of any particular Society will be found references to all Memoirs published by it bearing on the subject. Many of these Memoirs of a standard character are referred to again under the authors' names. In doing this I have laid myself open to the charge of invidious distinction, but as it was impossible to give all authors' names (which for recent papers are to be found in the Royal Society's Catalogue), and it was desirable to give some, I trust I may escape much censure for the selection I have made.

I have prepared this work, which has been no light task, in the hope that these references may be found useful to astronomers in guiding them to the particular literature giving information on the above-mentioned branches of Stellar Astronomy, and thereby reducing their labours in reading up the subject to a minimum.

* Double Stars. "Sidereal Messenger, The, Cincinnati, 1846–1848," inserted on the authority of *Silliman's Amer. Jour.*, 2nd Series, vol. 2, p. 442, as containing Mitchell's Observations of Double Stars. This work is not in the British Museum nor the libraries of the Royal Society and the Royal Astronomical Society.

London, 1876, *June*.

1. DOUBLE STARS.

Acad. des Sciences, Hist., vols. 1 (p. 266), 7 (p. 824).
Méms., 1720 (p. 141), 1775.
Comptes Rendus, vols. 6 (p. 920), 13 (p. 438), 28 (pp. 218, 407, 411, 597), 29 (pp. 116, 474), 32 (p. 50), 34 (p. 349), 35 (p. 741); 36 (p. 724), 38 (pp. 869, 883), 41 (p. 271), 48 (pp. 117, 375), 51 (p. 960), 56 (pp. 436, 845), 73 (p. 1232), 77 (p. 1234), 78 (pp. 342, 637, 1196), 79 (pp. 1246, 1463), 80 (pp. 171, 662).

American Acad., Proc., vol. 2 (p. 144), vol. 6; New Series, vol. 3 (p. 185).
Assn. Adv. Sci., Proc., 1872 (p. 33).

Annuaire du Bureau de Long., 1834.

Ast. Nach., Nos. 76, 77, 88, 94, 236, 240, 252, 280, 281, 289, 299, 303, 304, 317, 319, 324, 331, 338, 343, 344, 354, 362, 363, 364, 366, 411, 413, 427, 430, 444, 449, 452, 463, 467, 472, 486, 490, 496, 498, 506, 508, 520, 543, 549, 551, 565, 668, 678, 680, 768, 772, 806, 848, 858, 863, 868, 887, 967, 975, 990, 999, 1011, 1013, 1015, 1017, 1026, 1031, 1032, 1035, 1036, 1042, 1072, 1097, 1100, 1103, 1109, 1110, 1111, 1114, 1115, 1116, 1117, 1118, 1119, 1125, 1127, 1129, 1135, 1164, 1176, 1185, 1188, 1192, 1194, 1195, 1196, 1199, 1204, 1205, 1206, 1207, 1209, 1210, 1227, 1256, 1311, 1353, 1368, 1393, 1473, 1485, 1517, 1518, 1519, 1525, 1543, 1552, 1572, 1592, 1614, 1636, 1673, 1681, 1690, 1696, 1735, 1738, 1747, 1767, 1798, 1799, 1800, 1804, 1806, 1808, 1810, 1822, 1823, 1824, 1826, 1829, 1830, 1831, 1832, 1844, 1855, 1868, 1869, 1886, 1888, 1936, 1979, 1998, 2004, 2020, 2026, 2033, 2037, 2041, 2044, 2045, 2048, 2049, 2050, 2052, 2061, 2062, 2064, 2073, 2076, 2077, 2078, 2079, 2080, 2081, 2086 (to vol. 85); Ergänzungs-Heft, 1849 (p. 99).

Ast. Reg., 1863 to 1875 (*vide* Indices).

Ast. Soc., Roy., Mems., vols. 1, 2, 3, 4, 5, 6, 8, 9, 16, 17, 18, 19, 22, 25, 28, 29, 32, 35, 38, 40, 42.
Mon. Nots., vols. 1 to 35 (*vide* Indices).

Barclay, J. G., Leyton Observations, 1870, 1873.

Berlin Acad., Abhand., 1833 (p. 41).
Monatsb., 1853 (p. 287), 1865 (p. 135).
Ast. Jahrb., 1781 (p. 132), 1784 (p. 183), 1785 (pp. 132, 150), 1786 (p. 187), 1791 (pp. 217, 228), 1804 (p. 195), 1806 (p. 140), 1807 (p. 190), 1808 (pp. 154, 226), 1815 (p. 209), 1817 (p. 247), 1818 (p. 246), 1819 (p. 180), 1825, 1826 (p. 230), 1827 (p. 162), 1828 (p. 161), 1832 (p. 253).
Observations, vols. 1 (p. 142), 3 (p. 234).

Bessel, F. W., Verzeichniss von 257 auf der Königsberger Sternwarte beobachteten Doppelsternen, Ast. Nach., 88.
Beobachtungen der gegenseitigen Stellungen von 38 Doppelsternen, Berlin Acad., Abhand. 1833.

Astronomische Untersuchungen. Königsberg, 1841, vol. 1 (pp. 280, 296).
Abhand., von F. W. Bessel (Engelmann), vol. 2, 1876 (pp. 282–291).
Ast. Nach., 88, 240.
Bishop, George, Astronomical Observations, London, 1852.
Bode, J. E., Représentation des Astres, Berlin, 1782.
Descriptions des Constellations, Berlin, 1801.
Böhemian. Gesell. Abhand., vol. 2, 5th Series, 1842 (p. 465).
British Association Rep., 1850 (p. 23), 1855 (p. 25), 1858 (pp. 22, 29).
Brothers, A., Catalogue of Binary Stars, Man. Lit. Phil. Soc. Mems., 3rd Series, vol. 3, 1868.
Brunnow, Dunsink Observations, 1870.
Burnham, Ast. Soc., Roy., Mon. Nots., vols. 33 (pp. 351, 437), 34 (pp. 59, 382), 35 (p. 31).
Chambers, G. F., Descriptive Astronomy, Oxford, 1867 (p. 789).
Ast. Soc., Roy., Mon. Nots., vol. 28.
Comptes Rendus, *see* Acad. des Sciences.
Conn. des Temps, an 11, 1802 (p. 360), 1828 (p. 297), 1830 (pp. 65, 163), 1852 (p. 3), 1877 (p. 4).
Darby, W. A., The Astronomical Observer, London, 1864.
Darquier, Mémoire sur les Étoiles Doubles et le Mouvement des Fixes, Toulouse Acad. R., Méms., vol. 2, 1784 (p. 79).
Dawes, W. R., Ast. Soc., Roy., Mems., vols. 5, 8, 19, 35.
Micrometrical Measurements of Double Stars made at Ormskirk, Ast. Soc., Roy., Mems., vols. 8, 19.
Catalogue of Micrometrical Measurements of Double Stars. Ast. Soc., Roy., Mems., vol. 35.
Dembowski, Ast. Nach., 999, 1011, 1103, 1015, 1026, 1031, 1032, 1036, 1097, 1100, 1109, 1110, 1111, 1114, 1115, 1116, 1117, 1118, 1119, 1125, 1185, 1188, 1192, 1194, 1195, 1196, 1204, 1205, 1206, 1207, 1209, 1256, 1473, 1572, 1735, 1798, 1799, 1800, 1806, 1808, 1810, 1822, 1823, 1824, 1826, 1829, 1830, 1831, 1832, 1886, 1888, 1936, 1979, 2045, 2076, 2077, 2079, 2080, 2081, 2086.
Misure Micrometriche di 127 Stelle Doppie del Catalogo di Struve fatte negli anni 1852–5, Naples Accad. R., Mem., vol. 2 (p. 51).
Dieu, C., Tables donnant les Mesures Micrométriques de plus de 500 Étoiles Doubles et Multiples, Paris, 1843.
Doberck, W., On μ^2 *Boötis*, Irish Acad., Roy., Trans., vol. 25 (p. 481).
On the Binary Stars σ *Coronæ*, τ *Ophiuchi*, γ *Leonis*, ζ *Aquarii*, 36 *Andromedæ*, and ι *Leonis*, Irish Acad., Roy., Trans., vol. 25 (p. 581).
Ast. Nach., 2026, 2037, 2041, 2049, 2050, 2052, 2064.
Ast. Soc., Roy., Mon. Nots., vol. 35 (pp. 373, 397, 408).
Doppler, Christian, Über das farbige Licht der Doppelsterne, Böhm. Gesell. K. Abhand., vol. 2, 1842 (p. 465).
Vienna Acad., K.K. Sitzungs., vol. 8, 1852 (p. 91),

Dorpat Observations, vols. 1 (1817), 2 (1820), 3 (1822), 4 (1825), 9 (1842), 10 (1843), 11 (1845), 12 (1850), 13 (1856), 14 (1859), 15 (1863).

Dunlop, James, Ast. Soc., Roy., Mems., vol. 3.

Durham Observations, 1846, 1848.

Edinburgh, Jour. Sci., Brewster's, vols. 1 (p. 137), 3 (p. 281), 4 (p. 66), 7 (p. 88), 8 (p. 40), 9 (pp. 79, 90), 10 (p. 301).

Observations, 1855–1859 (p. 464).

Phil. Jour., vols. 9 (p. 334), 10 (pp. 102, 331).

Phil. Jour., New, vol. 50 (p. 159).

Phil. Jour., New, N.S., vols. 7 (p. 107), 19 (p. 64).

Soc. Roy., Trans., vols. 16 (p. 445), 23 (p. 371).

Encke, J. F., On the Calculation of the Orbits of Double Stars, Phil. Mag., vols. 9 (pp. 178, 405), 10 (p. 279), 11 (pp. 41, 102, 175, 414), Berlin, Ast. Jahrb., 1832 (p. 253).

Engelmann, R., Ast. Nach., 1518, 1673, 2004.

Federenko, J., Positions Moyennes pour l'Époque de 1790·0 des Étoiles circompolaires. St. Pétersbourg, 1854 (p. 156).

Ueber die Doppelsterne No. 1263 und 1516 des Dorpaters Catalogs.

Petersb., St., Acad. Imp. Sci., Bull. vol. 9, 1851, No. 7.

Gasparis, A., Sulla Determinazione delle Orbite delle Stelle doppie. Naples Accad., R., Atti, vol. 5, 1873, No. 11.

Geneva, Bibl. Univ. 1851.

Gledhill, J., Ast. Soc., Roy., Mems. vol. 42.

Gould's Ast. Jour., vol. 3 (pp. 82, 183).

Greenwich Observations, 1840 (p. 171), 1842 (p. 96), 1843 (p. 118), 1844 (p. 148) *γ Virginis*, 1846 (p. 117), 1847 (p. 91), 1848 (p. 78) 1849 (p. 68), 1850 (p. 68), 1851 (p. 52), 1852 (p. 68), 1853 (p. 56), 1855 (p. 60), 1856 (p. 68), 1858 (p. 88), 1859 (p. 88).

Herschel, J. F. W., Observations made with a 20-feet Reflecting Telescope, First Catalogue of 321 Double Stars, Ast. Soc., Roy., Mems., vol. 2.

Second Catalogue of 295 Double Stars, Ast. Soc., Roy., Mems., vol. 3.

Third Catalogue of 384 Double Stars, Ast. Soc., Roy., Mems., vol. 3.

Fourth Catalogue of 1236 Double Stars, Ast. Soc., Roy., Mems., vol. 4.

Fifth Catalogue of 2007 Double Stars, Ast. Soc., Roy., Mems., vol. 6.

Sixth Catalogue of 286 Double Stars, Ast. Soc., Roy., Mems., vol. 9.

Seventh Catalogue of 336 Double Stars, Ast. Soc., Roy., Mems., vol. 38.

General Catalogue of 10300 Multiple and Double Stars, Ast. Soc., Roy, Mems., vol. 40.

Micrometrical Measurements of 364 Double Stars, Ast. Soc., Roy., Mems., vol. 5.

Second Series of Micrometrical Measurements of 146 Double Stars, Ast. Soc., Roy., Mems., vol. 8.

Synopsis of all Sir W. Herschel's Micrometrical Measurements and Estimated Positions and Distances of Double Stars, Ast. Soc., Roy., Mems., vol. 35.

On the Orbits of Revolving Double Stars, Ast. Soc., Roy., Mems., vols. 5, 6, 18.

Results of Astronomical Observations made at the Cape of Good Hope, London, 1847.

Herschel, J., and South, J., Observations of the Apparent Distances and Positions of 380 Double and Triple Stars, Phil. Trans., 1824, part 3.

Herschel, W., Catalogue of 269 Double Stars, Phil. Trans, 1782 (p. 112).

Catalogue of 434 Double Stars, Phil. Trans., 1785 (p. 40).

Account of the Changes that have happened during the last 25 years in the relative situation of Double Stars, Phil. Trans., 1803 (p. 339), 1804 (p. 353).

On the Places of 145 New Double Stars, Ast. Soc., Roy., Mems., vol. 1 (p. 166).

Houseau, Naples Accad., R. Rendiconti, vol. 4 (p. 138).

Intellectual Observer, The, vols. 1 (pp. 142, 268, 373, 431), 2 (pp. 54, 133, 299, 370), 3 (pp. 52, 217, 449), 4 (p. 193), 5 (p. 139), 6 (pp. 58 350), 7 (pp. 139, 189), 8 (pp. 138, 212), 11 (pp. 277, 466), 12 (p. 376).

Jacob, W. S., Ast. Soc., Roy., Mems., vols. 16, 17, 28.

Madras Observations, 1848–1852 (p. 58 and Appendix).

Königsberg Observations, vols. 16 (p. 84), 17 (p. 114), 18 (p. 140), 24 (p. 69), 35 (p. 247), 36 (p. 264).

Labaume, B., Ast. Soc., Roy., Mems., vol. 4.

Leyden Observatory, Annalen, vol. 3, 1872, p. 179.

Lincei, Nuovi, Roma Accad. Pont., Atti, vols. 7, 1856 (p. 1), 13, 1860 (p. 8), 14, 1861 (p. 1), 19, 1866 (p. 259), 21, 1868 (p. 159), 1875, (Feb.).

Madras Observations, 1848–1852 (p. 58 and Appendix).

Mädler, J. H., Dorpat Observations, vols. 9, 10, 11, 12, 13, 14, 15.

Untersuchungen über die Fixstern-System, Mitau und Leipzig, 1847–8.

Populare Astronomie, 1861, (Tables).

Die Doppelsterne, Schumacher's Jahrbuch, 1839, p. 57.

Manchester Lit. Phil. Soc., Mems., 3rd Series, vol. 3, 1868.

Mayer, Christian, De novis in Coelo Sidereo Phaenomenis, Mannhemi, 1779, p. 127.

Vertheidigung neuer Beobacht. Gruendliche von Fixstern Trabanten, Mannheim, 1778.

Philadelphia Soc. Trans., vol. 2, 1786, p. 217.

Mitchell, Maria, Observations on some of the Double Stars, Silliman's Amer. Jour., 2nd Series, vol. 36, p. 38.

Munich Observatory, Annalen, vol. 17 (p. 296).

Naples, Accad. R., Mem., vols. 2, 1857 (p. 51).

Accad. R., Atti, vol. 5, 1873, No. 11.

Soc. Borb., Rendiconti, vols. 4, 1845 (p. 138), 5, 1856 (p. 95).

Accad. R., Rendiconti, vol. 3, 1864 (p. 220), 10, 1871 (p. 231), 1875 (Jan. Nov.).

Petersburgh, St., Acad. Imp. Sci., Mems., vols. 2, 1833 (p. 545), 4, 1841 (p. 337), 7, 1853, (p. 386).
Acad. Imp. Sci., Bull., vols. 6, 1840 (No. 11), 8, 1850 (Nos. 1, 2, 7, 11, 12), 9, 1851 (No. 7), 12, 1854 (Nos. 5, 6), 13, 1855 (No. 3); 7th Series, vols. 1 (p. 153), 7 (p. 282), 10 (pp. 14, 70, 213), 11 (p. 137), 12 (p. 73), 18 (p. 564), 19 (pp. 374, 449).
Philadelphia Soc. Trans., vol. 2, 1786, p. 217.
Phil. Mag., vols. 9 (pp. 178, 405), 10 (p. 279), 11 (pp. 41, 102, 175, 414).
Phil. Mag. Lond. Edin., vol. 35 (pp. 132, 386), 37 (p. 401).
Poggend. Ann. Phy. Chem., vols. 60 (p. 83), 66 (p. 321), 68 (p. 1), 81 (p. 270), 85, (p. 371).
Radcliffe Observations, 1850, 1853, 1860, 1861, 1862, 1863, 1864, 1865, 1866, 1867, 1868, 1869, 1870, 1871, 1872, 1873.
Romano Coll. Osser., Mem., 1842, 1852–56, 1863–66.
Royal Society, Phil. Trans., 1749 (p. 139), 1781 (p. 84), 1782 (p. 112), 1785 (p. 40), 1802 (p. 480), 1803 (p. 339), 1804 (p. 353), 1824, pt. 3, 1826 (p. 1).
Proc., vol. 10 (p. 133).
Savary, Sur la Détermination des Orbites que décrivent autour de leur centre de gravité deux étoiles très rapprochées l'une de l'autre. Conn. des Temps, 1830 (pp. 65, 163).
Schumacher's Jahrbuch, 1839 (p. 57).
Secchi, A., Descrizione del nuovo Osservatorio del Collegio Romano, Roma, 1856, Lincei Nuovi, Accad. Pont. Atti, vol. 7 (p. 19).
Catalogo di 1321 Stelle Doppie, Roma, 1860, Lincei Nuovi, Accad. Pont., Atti, vols. 13 (p. 1), 14 (p. 1).
Serie Seconda Misure Micrometriche, 1863–1866, Lincei Nuovi, Accad. Pont., Atti, vol. 21 (p. 159).
Comptes Rendus, vol. 48 (p. 375), Ast. Nach., 1614.
Sidereal Messenger, The (Mitchell, O. M.), Cincinnati, 1846–1848.
Silliman's American Journ., 1st Series, vol. 15 (p. 76); 2nd Series, vols. 2 (p. 280), 10 (p. 398), 25 (p. 129), 29 (p. 297), 33 (p. 286), 34 (p. 294), 35 (pp. 301, 407), 36 (p. 38), 37 (p. 233); 3rd Series, vols. 6 (p. 214), 9 (pp. 302, 457).
Smyth, C. P., Teneriffe, London, 1858 (p. 287).
Smyth, W. H., Cycle of Celestial Objects (Bedford Catalogue), London, 1844.
Ædes Hartwellianæ, London, 1851 (p. 287).
Speculum Hartwellianum, London, 1860 (p. 208).
Sidereal Chromatics.
Ast. Soc., Roy., Mems., vol. 8.
South, J., Phil. Trans., 1824, part 3, 1826 (p. 1).
Ast. Soc., Roy., Mems., vol. 1.
Struve, O., Catalogue révu et corrigé des Étoiles Doubles et Multiples, Pétersbourg, St., Acad. Imp. Sci., Mém., vol. 7, 1853.
Sur les Étoiles Doubles Artificielles, Pétersbourg St. Acad., Imp. Sci. Bull., vol. 13, 1855, No. 3.
Observations de l'Étoile Double 42 *Comæ*, Lincei Nuovi. Roma. Accad. Pont., Atti, vol. 19, 1866 (p. 259).

Struve, F. G. W., Catalogus 795 Stellarum Duplicium, Dorpat Observations, vol. 3, Dorpati, 1822.
Dorpat Observations, vols. 1, 2, 3, 4.
Catalogus Novus Stellarum Duplicium et Multiplicium, Dorpati, 1827.
Rapport sur les Étoiles Doubles, St. Pétersbourg, 1837.
Stellarum Duplicium et Multiplicium Mensuræ Micrometricæ, Petropoli, 1837.
Additamentum in F. G. W. Struve Mensuras Micrometricas, Pétersb. St. Acad. Imp. Sci., Mem., vol. 4, 1841, p. 337, and Bull. vol. 6, 1840, No. 11.
Catalogue de 514 Étoiles Doubles et Multiples, St. Pétersbourg, 1843.
Stellarum Fixarum Imprimis Duplicium et Multiplicium Positiones Mediæ, Petropoli, 1852.
Pétersb. St. Acad. Imp. Sci., Mem., vol. 2, 1833 (p. 545), 4, 1841 (p. 337), Bull., vol. 6, 1840, No. 11.
Toulouse Acad., Roy., Méms, vol. 2, 1784, p. 79.
Victoria, Phil. Inst., Trans., vol. 10 (p. 128).
Vienna, Acad., K.K. Sitzungs., vol. 8, 1852 (p. 91).
Villarceau, Yvon, Comptes Rendus, vols. 28 (pp. 218, 407, 411, 597), 29 (pp. 116, 474), 32 (p. 50), 34 (p. 349), 36 (p. 724), 38 (p. 869).
Pétersb., St., Acad., Imp. Sci., Bull., vols. 8, 1850 (Nos. 1, 2, 7, 11, 12), 12, 1854 (Nos. 5, 6).
Ast. Nach., 668, 678, 680, 858.
Conn. des Temps., 1852, 1877.
Méthode pour calculer les Orbites des Étoiles Doubles déduite de Considérations Géométriques, Conn. des Temps, 1877.
Washington Observations, 1862 (p. 508), 1863 (p. 279).
Webb, T. W., Celestial Objects for Common Telescopes, London, 1868.
The Intellectual Observer, vols. 1, 2, 3, 4, 5, 6, 7, 8, 11, 12.
Wichmann, M., Ast. Nach., Ergänzungs-Heft, 1849 (p. 99).
Wilson, J. M., Ast. Soc., Roy., Mems., vol. 42.
Winnecke, F. A. T., De Stella Coronæ Borealis Duplici (*η Coronæ*), Disputatio Astronomica Inauguralis, Berolini, 1856.
Zach, Baron de, Corresp., vol. 8 (pp. 216, 305, 367, 405, 513).
Monat. Corresp., vol. 26 (pp. 148, 295).

2. VARIABLE STARS.

Acad. des Sciences, Hist., vols. 2 (pp. 222, 263), 10 (pp. 496, 600).
Méms. 1706 (p. 115), 1709 (p. 33), 1713 (p. 45), 1719 (p. 94), 1759 (p. 227), 1788 (p. 240).
Comptes Rendus, vols. 13 (p. 438), 17 (p. 262), 26 (pp. 261, 484, 522, 545, 603), 27 (p. 111), 28 (p. 764) 30 (p. 358), 40 (pp. 31, 257), 41 (p. 950), 42 (p. 546), 53 (p. 479), 54 (p. 299), 56 (p. 636), 59 (p. 1016) 62 (pp. 1108, 1115), 63 (pp. 196, 229).
Acta Academiæ Curiosæ, 1696, Annus 4 (p. 118), Obs. 45.

American Assn. Adv. Sci., Proc., 1866 (pp. 5, 9).
Amsterdam, K. Akad., Verslagen, vol. 4, 1856 (p. 354).
Argelander, F. W, A., De Stella β *Lyræ* Variabili, Disquisitio, Bonnæ, 1844.
De Stella β *Lyræ* Variabili, Commentatio, Bonnæ, 1859.
Ast. Nach., 377, 398, 416, 417, 455, 624, 651, 845, 931, 959, 1029, 1045, 1063, 1649.
Ast. Nach., Ergänzungs-Heft, 1849, p. 31.
Beobachtungen und Rechnungen über Veränderliche Sterne, Bonner Beobachtungen, vol. 7 (p. 315).
Arrest, H. L. D', Resultater af en Teleskopisk Undersøgelser af egnen omkring det Sted paa Himmelen hvor Tycho's Nye Stjerne har viist sigi aarene 1572–1574, Copenhagen, Dansk. Vid. Selsk. Oversigt, 1864 (p. 1).
Ast. Gesell., Viertel., 1868 (p. 66), 1870 (pp. 12, 244), 1872 (pp. 2, 276), 1873 (p. 274), 1874 (p. 150), 1875 (p. 79).
Ast. Nach., Nos. 345, 354, 372, 377, 378, 383, 398, 416, 417, 429, 438, Beiträge, 455, 472, 487, 501, 624, 636, 638, 639, 648, 650, 651, 672, 742, 760, 768, 796, 804, 806, 832, 839, 845, 849, 858, 892, 918, 931, 958, 959, 991, 996, 1000, 1007, 1009, 1011, 1015, 1019, 1023, 1029, 1031, 1035, 1045, 1049, 1054, 1055, 1059, 1060, 1062 to 1066, 1069, 1070, 1072, 1073, 1080, 1089, 1091, 1099, 1103, 1105, 1118, 1120, 1124, 1128, 1129 1130, 1132, 1133, 1134, 1143, 1147, 1152, 1156, 1159, 1183, 1188, 1190, 1205, 1208, 1221, 1224, 1231, 1234, 1236, 1238, 1244, 1248, 1265, 1281, 1288, 1294, 1300, 1302, 1304, 1308, 1312, 1313, 1320, 1325, 1326, 1330, 1337, 1350, 1353, 1358, 1376, 1384, 1403, 1410, 1420, 1449, 1458, 1467, 1477, 1484, 1485, 1486, 1491, 1496, 1500, 1513, 1521, 1523, 1529, 1530, 1531, 1537, 1540, 1542 to 1547, 1569, 1570, 1574, 1577, 1586, 1590 to 1593, 1597, 1603, 1613, 1615, 1616, 1620, 1622, 1627, 1628, 1635, 1642, 1648, 1651, 1659, 1665, 1672, 1677, 1687, 1689, 1690, 1700, 1702, 1708, 1713, 1727, 1729, 1733, 1741, 1745, 1760, 1762, 1767, 1769, 1770, 1774, 1777, 1781, 1785, 1793, 1805, 1807, 1816, 1817, 1830, 1832, 1835, 1843, 1856, 1857, 1861, 1862, 1867, 1868, 1870 to 1872, 1876, 1880, 1885, 1888, 1893, 1895, 1896, 1901, 1904 to 1907, 1911, 1912, 1915, 1920, 1924, 1931, 1932, 1952, 1958, 1964, 1969, 1972, 1975, 1977, 1978, 1981, 1986, 1988, 1991, 2001, 2026, 2031, 2041, 2054, 2055, 2065, 2071, 2074, 2075, 2077, 2081 (to vol. 85).
Ast. Reg., 1863 to 1875 (vide Indices).
Ast. Soc., Roy., Mems., vols. 11, 12.
Mon. Nots., vols. 1 (pp. 33, 75, 192), 4 (pp. 121, 132, 195). 5 (pp. 10, 11, 232), 6 (pp. 9, 23), 7 (p. 95), 8 (pp. 127, 155, 192), 9 (pp. 18, 37), 10 (p. 142), 11 (pp. 46, 230), 13 (pp. 33, 52, 85, 186, 271), 14 (p. 188), 15 (p. 199), 16 (pp. 56, 65, 174, 185, 201), 17 (pp. 23, 148, 199, 200, 235, 266), 18 pp. 135, 283, 311), 19 (pp. 3, 54, 77, 202), 20 (pp. 22, 37,

283, 331), 21 (pp. 68, 188, 230), 22 (pp. 44, 47, 155, 285), 23 (pp. 64, 91, 207), 24 (pp. 2, 65), 25 (pp. 66, 192, 208), 26 (pp. 83, 214, 240, 272, 292, 310), 27 (pp. 5, 57, 243, 316), 28 (pp. 45, 200, 225, 266), 29 (p. 298), 30 (p. 179), 31 (pp. 84, 210, 226, 249), 32 (pp. 61, 89), 34 (pp. 54, 251, 410), 35 (pp. 126, 340, 374, 396) (to vol. 35).

Auwers, A., Ast. Nach., 1183, 1238.

Baxendale, J., and Knott, G., On the Method of Observing Variable Stars, 1863, Ast. Reg., 1863.

Belgium, Acad. Roy., Bull., vol. 21, 2nd Series (p. 535).

Berlin, Akad. Monatsber., 1855 (p. 695).

Ast. Jahrb., 1786 (pp. 244, 248), 1787 (p. 138), 1788 (pp. 161, 170, 182), 1789 (pp. 172, 228), 1791 (pp. 174, 252), 1793 (p. 195), 1794 (p. 252), 1796 (p. 192), 1797 (p. 165), 1798 (p. 224), 1801 (p. 154), 1802 (p. 249), 1803 (p. 106), 1804 (p. 150), 1807 (p. 168), 1810 (p. 140), 1813 (pp. 224, 234), 1814 (p. 143), 1816 (pp. 131, 175), 1817 (p. 218), 1818 (p. 96), 1819 (pp. 112, 176), 1820 (pp. 103, 183), 1821 (p. 209), 1822 (p. 119), 1827 (p. 186).

Berolinensia Miscellanea, Berolini, 1710, p. 208.

Bishop, G., Astronomical Observations, 1852 (p. 241).

Bode, J. E., Recueil de Tables Astronomiques, Berlin, 1776, vol. 1 (p. 212).

Brahe, Tycho, Opera, tome 1, 1610 (p. 297).

Brit. Assn. Rep., 1858 (p. 29), 1859 (p. 36), 1861 (p. 24), 1866 (p. 8).

Cassini, Éléments d'Astronomie, 1740 (p. 57).

Chambers, G. F., Descriptive Astronomy, 1867 (p. 576).

Ast. Soc., Roy., Mon. Nots., vol. 25 (p. 208).

Cherbourg Soc. Sci. Mém., vol. 1 (p. 360).

Colombe, Lud. Delle, Discorso sopra la Nuova Stella apparita l'Ottobre passato, 1604, Firenze, 1606.

Comptes Rendus, *see* Acad. des Sciences.

Conn. des Temps, 1792 (p. 287); an 7, 1798, 1799 (p. 426); an 12, 1803 (p. 411); an 15, 1807 (p. 379); 1820 (p. 414); 1867 (p. 45); 1870 (p. 69).

Copenhagen, Dansk. Vid. Selsk. Oversigt, 1864 (p. 1).

Dantzig, Gesell. Naturforschenden, Neuester Schrift, vol. 1, 1820.

Darby, W. A., The Astronomical Observer, London, 1864.

Darquier, Sur les Étoiles nouvelles et périodiques, Toulouse Acad. Roy., Mém., vol. 2, 1784 (p. 169).

Edin. Phil. Jour., vol. 9 (p. 219).

Finska, Vetens. Soc. Öfversight, Forhand., 1865 (p. 47), 1866 (p. 10).

Geneva, Bibl. Univ., 1857.

Gould's Ast. Jour., vols. 4, 5, 6.

Harvard Coll. Obsry., Annals, vol. 5 (p. 124).

Hevelius, J., Mercurius in Sole visus, 1662 (p. 146).

Cometographia, p. 374.

Intellectual Observer, vols. 3 (p. 212), 7 (p. 133), 9 (p. 382).

Jour. Sci., Quar., 1866 (p. 376).

Kepler, J., De stella nova in pede *Serpentarii*, Pragæ, 1606.
Opera omnia, 1859, vol. 2 (pp. 278 note, 617).
Knott, G., On the Method of Observing Variable Stars, 1863, Ast. Reg. 1863.
Man. Lit. Phil. Soc., Proc., vols. 4 (p. 55), 5 (pp. 59, 90, 124), 6 (p. 101).
Königsberg Observations, vols. 31 (p. 131), 35 (p. 239).
Lindenau, Zeitschrift für Astronomie, vols. 1 (p. 229), 2 (p. 181), 4 (pp. 185, 316), 6 (p. 282).
Madras Jour. Lit. Sci., N.S., vol. 7.
Mädler, J. H., Populare Astronomie, 1861 (Tables).
Manchester Lit. Phil. Soc., Mems., 3rd Series, vol. 3, 1868.
Proc., vols. 1 (p. 197), 3 (p. 195), 4 (pp. 22, 54), 5 (pp. 28, 59, 88, 109, 124, 191), 6 (pp. 35, 72, 99, 101).
Maraldi, Acad. des Sciences, Méms., 1709 (p. 33), 1713 (p. 45), 1719 (p. 94).
Mauri, A., Considerazioni sopra alcuni luoghi del Discorso di Ludovico delle Colombe intorno alla Stella apparita 1604, Firenze, 1606.
Montpellier Acad. Sci., Méms., vols. 3 (p. 429), 4 (p. 37).
New South Wales, Phil. Soc. Trans., 1862–1865 (p. 126).
Soc., Roy., Trans., 1871 (p. 15).
Olbers, Noch etwas über den veränderlichen Stern χ *Bayeri* im Schwan, Schumacher's Jahrbuch, 1841 (p. 83).
Oudemans, J. A. C., Zweijæhrige Beobachtungen der meisten jetzt bekannten veræenderlichen Sterne, Amsterdam Akad., K., Abhand., 1856.
Amsterdam, K. Akad., Verslagen, vol. 4, 1856 (p. 354).
Petersburg, St., Acad. Imp. Sci., Bull., 1860, vol. 1 (p. 173).
Petropolitanæ Novi Commen., 1747–1748 (p. 477).
Phil. Mag. Lond. and Edin., vols. 15, 4th Series (p. 359), 39 (p. 363).
Pigott, Edw., Phil. Trans., 1785 (p. 127), 1786 (p. 189), 1797 (p. 133), 1805 (p. 131).
Pogson, N., Radcliffe Observations, 1854, 1856.
Ast. Soc., Roy., Mon. Nots., vol. 17 (p. 23).
Ast. Nach., 1132.
Riccioli, Almagestum Novum, Bononiæ, 1653, tom. 2, p. 130.
Radcliffe Observations, 1851 (Appx.), 1854 (p. 281), 1856 (p. 105).
Romano Coll. Osser., Mems., 1842 (p. 5).
Royal Society, Phil. Trans., 1666 (pp. 349, 372, 382), 1667 (p. 460), 1668 (p. 683), 1670 (Nos. 65, 66), 1671, No. 73 (p. 5126), 1676 p. 565), 1677 (p. 853), 1715 (pp. 226, 354), 1760 (p. 498), 1780 (p. 338), 1783 (p. 474), 1784 (pp. 1–5, 287), 1785 (pp. 127, 153), 1786 (pp. 48, 189), 1792 (p. 24), 1796 (p. 452), 1797 (p. 133), 1805 (p. 131).
Schmidt, Julius, Ast. Nach., 1055, 1059, 1060, 1062, 1065, 1066, 1069, 1073, 1080, 1091, 1099, 1103, 1118, 1124, 1128, 1130, 1133, 1134, 1150, 1221, 1236, 1244, 1294, 1300, 1302, 1745, 1767, 1770, 1805, 1832, 1861, 1867, 1870, 1871, 1880, 1888, 1893, 1895, 1896, 1905, 1911, 1912, 1932, 1958, 1969, 1975, 2071, 2074, 2075, 2077.
Schönfield, E., Catalog von Veræenderlichen Sternen, Mannheim.
Zweiter Catalog von Veræn., Sternen, Mannheim, 1875.

Vienna, Acad. KK., Sitzber., vol. 42 (p. 146).
Ast. Nach., 1628, 1648, 1729, 1774, 1777, 1817, 1857, 1906, 19
1972, 1991, 2065.
Schönfeld and Winnecke, Ast. Gesell. Viertel., 1868 (p. 66).
Schumacher's Jahrbuch, 1841, 1844.
Silliman's American Jour., 2nd Series, vols. 36 (p. 144), 42 (pp. 79, 80, 3
Smyth, W. H., Speculum Hartwellianum (p. 101).
Stockholm, K. Vet. Acad., Handlingar, 1779 (pp. 249, 335).
Student, The, vol. 3 (pp. 281, 370).
Tasmania Soc., Roy., Mon. Nots., 1868 (p. 14), 1870 (p. 21), 1871 (pp.
68), 1872 (p. 27).
Toulouse, Acad., Roy., Méms., vol. 2, 1784 (p. 169).
Victoria, Phil. Inst., Trans., vol. 10 (pp. 11, 106).
Vienna, Acad. KK., Sitz., vol. 42 (p. 146).
Wargentin, P., Om den förändérliga Stjernan i Hvalfiskens Constellati
(*Cetus*), Stockholm, K. Vet. Acad., Handlingar, 1779 (
249, 335),
Washington Observations, 1862 (p. 511).
Westphal, J. H., Ueber die Periodisch veränderlichen Sterne, Dant
Gesell. Naturfors., Neuester Schrift., vol. 1, 1820.
Winnecke, Ast. Nach., 1120, 1224, 1816, 1876.
Zach, Baron de, Corresp., vols. 5 (p. 174), 8 (p. 95), 13 (p. 234).
Monat. Corresp., vol. 3 (p. 615), 21 (p. 461), 26.

3. RED STARS.

Acad. des Sciences, Comptes Rendus, vols. 30 (p. 359), 67 (p. 374).
Ast. Gesell., Viertel., 1874 (p. 252).
Ast. Nach., Nos. 636, 648, 712, 713, 742, 839, 991, 1045, 1132, 1591, 16
1737, 1862, 1902, 1905, 1964, 1977, 2016 (to vol. 85).
Ast. Reg., 1866 (p. 242), 1872 (p. 264), 1873 (p. 19), 1874 (pp. 11, 11
1875 (p. 98).
Ast. Soc., Roy., Mon. Nots., vols. 10 (p. 141), 11 (p. 46), 17 (p. 65),
(p. 136), 25 (p. 212), 28 (p. 196), 31 (p. 84), 33 (p. 6
34 (pp. 54, 103, 251, 410) (to vol. 35).
Brit. Assn. Rep., Trans., 1863 (p. 10).
Chambers, G. F., Descriptive Astronomy, Oxford, 1867, p. 583.
Comptes Rendus, *see* Acad. des Sciences.
Conn. des Temps, an 15, 1807 (p. 378).
Herschel, J. F. W., Results of Ast. Observations at the Cape of Good Ho
(p. 448).
Intellectual Observer, vols. 6 (p. 112), 8 (p. 142), 9 (p. 176), 10 (p. 11
11 (pp. 149, 275).
Lalande, J., Conn. des Temps, an 15, 1807 (p. 378).
Manchester, Lit. Phil., Soc., Proc., vol. 5 (p. 191).
Romano Coll. Osser., Mem., 1843, 1851, 1852-56.
Schjellerup, H. C. F. C., Ast. Nach., 1591, 1613.
Ast. Gesell., Viertel., 1874 (p. 252).

Smyth, W. H., Sidereal Chromatics (p. 19).
Student, vol. 5 (p. 489).
Webb, T. W., Intellectual Observer, vols. 6, 8, 9, 10, 11.
Student, vol. 5.
Zach, Baron De, Corresp., vol. 8 (p. 95).

4. NEBULÆ AND CLUSTERS.

Abbe, Cleveland, The very much extended Nebulæ of Sir J. Herschel's Gen. Cat., Silliman's Amer. Jour., 3rd Series, vol. 9 (p. 42).
Acad. des Sciences, Hist., vol. 10 (p. 118).
Méms. 1707 (p. 354), 1731 Aur. Bor., (p. 246), 1734 (p. 78), 1755 (p. 194), 1759 (p. 453), 1771 (p. 435), 1777 (p. 440), 1807 (p. 206).
Comptes Rendus, vols. 13 (p. 449), 24 (p. 1021), 27 (p. 112), 28 (p. 537), 30 (p. 358), 37 (p. 874), 40 (p. 775), 54 (p. 299), 55 (pp. 606, 792), 56 (p. 637), 58 (p. 72), 60 (p. 543), 65 (p. 63), 66 (pp. 306, 643), 73 (p. 825), 74 (p. 444), 76 (p. 1073), 77 (p. 1364).
Alexander, Stephen, On the origin of the Forms and the present condition of some of the Clusters of Stars, and several of the Nebulæ, Gould's Ast. Jour., vol. 2 (p. 95).
Amer. Acad. Mems., N.S., vol. 3 (pp. 75, 87).
Proc., vol. 6 (p. 177).
Assn. Adv. Sci. Proc., 1870 (p. 40).
Phil. Soc. Trans., vol. 7 (p. 165).
Arago, On Nebulæ, Edin. New. Phil. Jour., vol. 33 (p. 307).
Arrest, H. L. D', Resultate aus Beobachtungen der Nebelflecken und Sternhaufen, 1856, Sachs. Gesell. K. Abhand., vol. 3, 1857 (p. 293).
Instrumentum Magnum Æquatorium Dissertatio, Havniæ, 1861.
Undersøgelser over de Nebulose Stjerner Kjøbenhavn, 1872.
Verzeichniss von 215 Neuen Nebelflecken, Ast. Nach., No. 1500.
Zweites Verzeichniss von Neuen Nebelflecken, Ast. Nach., No. 1537.
Ast. Nach., Nos. 1366, 1369, 1393, 1500, 1537.
Ast. Nach., Nos. 104, 113, 120, 261, 281, 383, 391, 536, 702, 712, 713, 839, 855, 895, 972, 995, 997, 1018, 1072, 1290, 1293, 1302, 1337, 1341, 1357, 1360, 1366, 1368, 1369, 1378, 1379, 1391 to 1394, 1397, 1407, 1409, 1440, 1453, 1463, 1477, 1500, 1504, 1508, 1513, 1520, 1531, 1537, 1541, 1542, 1553, 1555, 1556, 1563, 1566, 1571, 1585, 1599, 1624, 1631, 1651, 1665, 1666, 1667, 1672, 1678, 1683, 1689, 1698, 1810, 1864, 1867, 1885, 1898, 1908, 1939, 1972, 1977, 2045 (to vol. 85).
Ast. Reg., 1863 to 1873 (vide Indices).
Ast. Soc., Roy., Mems., vols. 2, 3, 23, 33, 36.
Ast. Soc., Roy., Mon. Nots., vols. 3 (p. 167), 8 (p. 31), 10 (p. 141), 12 (p. 208), 14 (p. 74), 17 (pp. 225, 245), 18 (p. 8), 21 (pp. 32, 203), 22 (pp. 150, 242, 248, 277), 23 (p. 32), 24 (pp. 7, 65, 171, 177), 25 (pp. 62, 153, 190), 26 (pp. 65, 71, 208), 27 (pp. 257, 315), 28 (pp. 154, 162, 200, 225, 246),

29 (pp. 82, 329, 337), 30 (p. 184), 31 (pp. 226, 249), 32 (pp. 23, 61, 231, 359), 33 (pp. 66, 406, 433, 558), 34 (pp. 75, 269), 35 (pp. 135, 265) (to vol. 35).

Auwers, A., William Herschel's Verzeichnisse von Nebelflecken und Sternhaufen, 1862, Königsberg Observations, vol. 34.

Verzeichniss der Oerter von Vierzig Nebelflecken, Ast. Nach., 1392.

Belgium, Acad. Roy., Bull., 2nd Series, vol. 13 (p. 445).

Berlin, Acad. Mems., 1794–1795 (p. 179).

Berlin, Ast. Jahrb., 1779 (p. 65), 1782 (p. 155), 1784 (pp. 181, 231), 1785 (p. 230), 1786 (p. 164), 1788 (p. 238), 1791 (p. 157), 1794 (p. 151), 1797 (p. 184), 1799 (p. 235), 1801 (pp. 126, 178), 1802 (p. 231), 1803 (pp. 106, 153), 1805 (p. 211), 1807 (p. 129), 1818 (p. 97), 1826 (p. 110), 1827 (p. 134).

J. E., Recueil de Tables Astronomiques, Berlin, 1776, vol. 1 (p. 206).

Représentation des Astres, Berlin, 1782.

Observations sur la Distribution des Nébuleuses et des groupes d'Étoiles dans le firmament, Berlin Acad., Mémes., 1794, 1795 (p. 179).

Bond, G. P., An Account of the Nebula in *Andromeda*, Amer. Acad., Mems., New Series, vol. 3 (p. 75).

Observations on the Great Nebula of *Orion*, Harvard Coll., Annals, vol. 5.

Bond, W. C., Description of the Nebula about *θ Orionis*, Amer. Acad., Mems., N.S., vol. 3 (p. 87).

British Assn. Rep., Trans., 1852 (p. 22), 1862 (p. 14), 1869 (p. 20).

Comptes Rendus, *see* Acad. des Sciences.

Conn. des Temps, 1784 (pp. 227, 268, 270), 1787 (p. 238), an 11, 1802 (p. 361).

Cysatus, J. B. de, Lucerne, Mathemata Astronomica de loco Motu Magnitudine et causis Cometae annorum 1618 et 1619, Ingoldstadii, 1619 (p. 75) (Ast. Nach. 895).

Darby, W. A., The Astronomical Observer, London, 1864.

Derham, W., Phil. Trans., 1733.

Dunlop, J., A Catalogue of Nebulæ and Clusters of Stars (629) in the Southern Hemisphere, Phil. Trans., 1828 (p. 113).

Edin. Phil. Jour., Brewster's, vol. 10 (p. 282).

New, vol. 33 (p. 307).

Fennicæ Soc. Sci. Acta, vol. 8 (p. 55).

Firenze, Soc. Ital. Mem., 1868, 3rd Series, vol. 1, part 2.

Galilei, G., Sidereus Nuncius, 1682.

Geneva Bibl. Univ., 1863.

Gould's Ast. Jour., vols. 2 (p. 95), 3 (p. 71), 5 (p. 16).

Harvard Coll. Obs. Annals, vol. 5.

Herschel, J. F. W., Observations of Nebulæ and Clusters of Stars made at Slough with a 20-ft. Reflector between the years 1825 and 1833, Phil. Trans. 1833 (p. 359).

General Catalogue of 5079 Nebulæ and Clusters of Stars, Phil. Trans., 1864.

Observations with a 20-ft. Reflecting Telescope, Ast. Soc., Roy., Mems., vol. 2.

Results of Astronomical Observations at the Cape of Good Hope, London, 1847.

Herschel, W., Catalogue of 1000 New Nebulæ and Clusters of Stars, Phil. Trans., 1786 (p. 457).

Catalogue of a second 1000 new Nebulæ and Clusters of Stars, Phil. Trans., 1789 (p. 212).

Catalogue of 500 New Nebulæ, Nebulous Stars, Planetary Nebulæ and Clusters of Stars, Phil. Trans., 1802 (p. 477).

Phil. Trans., 1784 (p. 437), 1791 (p. 71), 1811 (p. 269), 1814 (p. 248), 1818 (p. 429).

Holden, E. S., On Supposed Changes in the Nebula M 17, Silliman's Amer. Jour., 3rd Series, vol. 11 (p. 341).

Huyghens, C., Systema Saturnium, Hagæ-Comitis, 1659 (p. 8).

Intellectual Observer, The, vols. 2 (pp. 353, 418), 4 (pp. 56, 257, 346, 448), 5 (pp. 54, 138), 6 (pp. 115, 343, 399), 7 (p. 186), 8 (pp. 207, 297), 9 (p. 175), 10 (p. 286), 11 (pp. 275, 384, 459), 12 (p. 380).

Irish Acad., Roy., Proc., vols. 3 (p. 127), 4 (pp. 124, 236).

Journal of Science, Quar., 1872 (p. 308).

Königsberg Observations, vols. 34, 35 (p. 193).

Krueger, A., Der Sternhaufen *h Persei*, Fennicæ Soc. Sci. Acta, vol. 8 (p. 55).

Lacaille, Abbé De, Sur les Étoiles Nébuleuses du Ciel Austral, Acad. des Sciences, Mém., 1755 (p. 194), Conn. des Temps, 1784 (p. 270).

Lamont, J., Ueber die Nebelflecken, Address, München, 1837.

Munich Observatory, Annalen, vol. 17 (p. 305).

Lassell, W., Observations of the Nebula of *Orion*, made at Valetta, Ast. Soc., Roy., Mems., vol. 23.

A Catalogue of New Nebulæ discovered at Malta, Ast. Soc., Roy., Mems., vol. 36.

Laugier, E., Sur un Nouveau Catalogue de Nébuleuses observées à l'Observatoire de Paris, Comptes Rendus, vol. 37 (p. 874).

Le Gentil, Remarques sur les Étoiles Nébuleuses, Acad. des Sciences, 1759, (p. 453).

Liapounov, *see* Struve, Otto.

Lincei Nuovi, Accad. Pont. Roma, Atti, vol. 7, 1856 (p. 67).

Littrow, Sterngruppen und Nebelmassen des Himmels, Wien, 1835.

Mannheim Observations, 1862, 1875.

Messier, C., Catalogue des Nébuleuses et des Amas d'Étoiles, Acad. des Sciences, Mém., 1771 (p. 435).

Catalogue des Nébuleuses et des Amas d'Étoiles, Conn. des Temps, 1784 (pp. 227, 268), Berlin, Ast. Jahrb., 1786 (p. 164).

Catalogue des Nébuleuses et des Amas d'Étoiles observées à Paris, Conn. des Temps, 1787 (p. 238), Königsberg Observ., vol. 34.

Observations et Dessin de la Belle et Grande Nébuleuse de la Ceinture d'*Andromède*, Acad. des Sciences, Mém., 1807 (p. 206).

Munich Observatory, Annalen, vol. 17 (p. 305).
New South Wales, Soc., Roy., Trans., 1871 (p. 15), 1872 (p. 84).
Nichol, J. P., Architecture of the Heavens, 1851.
System of the World, Edinburgh, 1848.
Petersburg, St., Acad. Imp. Sci., Mems., vol. 5, 7th Series, 1863, No. 4.
Bull., vols. 7 (pp. 18, 353), 9, 1866 (p. 569), 14 (p. 248), 16, 1858, No. 8.
Pihl, O. A. L., Micrometric Examination of Stellar Cluster in *Perseus*, Christiania, 1869, Ast. Soc., Roy., Mon. Nots., vol. 28 (p. 246), 29 (p. 329).
Phil. Mag. Lond. and Edin., vol. 39, 4th Series (p. 401).
Proctor, R. A., Essays on Astronomy, 1872 (pp. 317, 338).
Romano Coll. Osser., Mem., 1839 (p. 31), 1842 (p. 27), 1852–56, 1863–66.
Rosse, Earl of, Observations on some of the Nebulæ, Phil. Trans, 1844 (p. 321), 1850 (p. 499).
On the Construction of Specula of Six Feet, Phil. Trans., 1861 (p. 681).
Royal Society, Phil. Trans., 1666 (p. 381), 1667 (p. 459), 1716 (p. 390), 1733 (pp. 70, 254), 1781 (p. 82), 1784 (p. 437), 1785 (p. 213), 1786 (p. 457), 1789 (p. 212), 1791 (p. 71), 1800 (p. 53), 1802 (p. 477), 1811 (p. 269), 1814 (p. 248), 1818 (p. 429), 1828 (p. 113), 1833 (p. 359), 1844 (p. 321), 1850 (p. 499), 1861 (p. 681), 1864 (p. 1), 1866 (p. 381), 1868 (pp. 57, 529).
Proc., vols. 12 (p. 269), 14 (p. 39), 16 (p. 322, 383, 417, 451), 19 (p. 18), 20 (p. 383).
Sachs, Gesell., Königs., Abhandl., vol. 3, 1857 (p. 293).
Schmidt, J. F. J., Mittlere oerter von 110 Nebeln., Ast. Nach., 1678.
Schönfeld, E., Mannheim Observations, 1862, 1875.
Schroeter, J. H., Bemerkungen über *Orions* Lichtnebel, Aphroditographische Fragmente, Helmstedt, 1796, p. 245.
Schultz, H., Upsala Observations, 1863.
Upsala Univ. Arsskr., 1864.
Micrometrical Observations of 500 Nebulæ, Upsala Reg. Soc. Sci., Nova Acta, vol. 9, 1874.
Mikrometrisk Bestämning af 104 Stjernor inom Teleskopiska, Stjerngruppen 20 *Vulpeculæ*, Stockholm Akad. Vet., Köngl., vol. 11.
Ast. Nach., 1541.
Secchi, A., Quadro Fisico del Sistema Solare, 1859.
Romano Coll. Osserv., Mem., 1863–66.
Lincei Nuovi, Accad. Pont. Roma, vol. 7, 1856 (p. 67).
Sulla Grande Nebulosa di *θ Orione*, Firenze Ital. Soc., Mem., 1868, vol. 1, 3rd Series, pt. 2.
Sidereal Heavens, Theory of Structure of, London, 1842.
Silliman's Amer. Jour., 1st Series, vols. 40 (p. 37), 44 (p. 375); 2nd Series, vols. 4 (p. 427), 9 (p. 140), 15 (p. 300), 33 (p. 436), 35 (p. 101), 37 (p. 198); 3rd Series, vols. 9 (p. 42), 11 (p. 341).
Smithsonian Report, 1863 (p. 299).

Smyth, W. H., Cycle of Celestial Objects, London, 1844.
Speculum Hartwellianum, London, 1860.
Smith, H. L., and Mason, E. P., Observations on Nebulæ with a 14-feet Reflector, Amer. Phil. Soc. Trans., vol. 7, N.S. (p. 165).
Stockholm Akad. Vet., Köngl., vol. 11.
Struve, Otto, and Liapounov, Sur la Nébuleuse d'*Orion*, Pétersb., St., Acad. Imp. Sci., Méms., vol. 5, 7th Series, 1863, No. 4.
Struve, W., Catalogus Novus Stellarum Duplicium, Dorpati, 1827 (p. 88).
Études d'Astronomie stellaire, St. Pétersbourg, 1847.
Student, The, vols. 1 (pp. 113, 454), 3 (p. 424).
Tasmania Soc., Roy., Mon. Nots., 1864 (p. 3), 1868 (p. 14), 1870 (p. 21), 1871 (pp. 17, 68), 1872 (p. 27).
Upsala Reg. Soc. Sci. Nova Acta, vol. 9, 3rd Series.
Victoria Phil. Inst. Trans., vol. 10 (pp. 11, 106).
Vogel, H. C., Beobachtungen von Nebelflecken und Sternhaufen, Leipzig, 1867 and 1875. Verzeichnisse von 100 Nebelflecken, Ast. Nach., 1667.
Webb, T. W., Celestial Objects for Common Telescopes, 2nd ed., London, 1868.
Intellectual Observer, The, vols. 2, 4, 5, 6, 7, 8, 9, 10, 11, 12.
Zach, Corresp., vol. 14 (p. 409).
Monat. Corresp., vol. 10 (p. 220).

5. PROPER MOTIONS OF STARS.

Acad. des Sciences, Hist., vol. 10 (p. 278).
Méms., 1727 (p. 19), 1738 (p. 331), 1758 (p. 34), 1769 (p. 1).
Comptes Rendus, vols. 16 (p. 494), 17 (p. 888), 24 (p. 1021), 26 (p. 64), 28 (p. 573), 44 (p. 1184), 46 (p. 699), 47 (p. 68), 49 (pp. 870, 980, 993), 53 (p. 80), 66 (p. 1200), 75 (p. 854).
Airy, G. B., On the Movement of the Solar System in Space, Ast. Soc., Roy., Mems., vol. 28.
American Acad., Proc., New Series, vol. 2 (p. 82), vol. 3 (pp. 52, 210).
Assn. Adv. Sci., Proc., 1850 (p. 44), 1870 (p. 25).
Argelander, F. W. A., Ueber die eigene Bewegung des Sonnensystems, Petersb., St., Acad. Imp. Sci., Mems., Divers Savants, vol. 3 (p. 561)
Ditto, Bull., vol. 2, 1837, Nos. 8 and 9.
Ueber die eigene Bewegung des Sonnensystems, Ast. Nach., 363, 364, 398.
Untersuchungen über die Eigenbewegungen von 250 Sternen, Bonner Beobachtungen, vol. 7.
Armagh Catalogue, Dublin, 1859, p. xxxiii.
Assas-Montdardier, Sur la Détermination de la Parallaxe et du Mouvement propre en Déclinaison des Étoiles, Conn. des Temps, 1831 (p. 120).
Ast. Gesell. Pub., 1868, No. 7.
Ast. Nach., Nos. 105, 331, 363, 398, 455, 475, 483, 485, 496, 498, 504, 513 to 516, 520, 566, 570, 590, 616, 618, 620, 641, 661 to 663, 668, 674, 734, 745 to 748, 750, 786, 811, 812, 880, 889, 994, 997, 1007, 1036, 1062, 1066, 1068, 1098, 1129, 1135,

1142, 1231, 1288, 1296, 1312, 1366, 1371, 1383, 1411, 1416, 1433, 1442, 1485, 1511, 1695, 1797, 1864 (to vol. 85), Ergänzungs-Heft, 1849, (p. 119).

Ast. Reg., 1864 (pp. 37, 59, 82), 1867 (p. 105), 1868 (p. 236), 1870 (p. 127).

Ast. Soc., Roy., Mems., vols. 5, 19, 28, 29, 32, 33, 42.

Mon. Nots., vols. 2 (p. 47), 4 (p. 82), 5 (p. 265), 6 (p. 136), 8 (p. 16), 10 (pp. 118, 172), 14 (p. 159), 18 (p. 288), 19 (pp. 61 175), 20 (p. 202), 21 (p. 42), 22 (p. 145, 148), 23 (pp. 18, 67, 166, 203), 24 (p. 36), 27 (p. 238), 30 (p. 9), 31 (pp. 40, 42), 33 (pp. 52, 102, 105), 34 (p. 25), 35 (pp. 323, 356, 361 397), to vol. 35.

Auwers, A., Untersuchungen über veränderliche Eigenbewegung, Inaugural Dissertation, Königsberg, 1862.

Untersuchungen über veränderliche Eigenbewegungen, Ast. Gesell. Pub., 1868, No. 7.

Parallaxen Bestimmung, Ast. Nach., 1411 to 1416.

Baily, Francis, On the Proper Motion of the Fixed Stars, Ast. Soc., Roy., Mems., vol. 5.

Belgium Acad. R., Mémis., vols. 32, 34, 38.

Bull., 2nd Series, vols. 8 (p. 146), 16 (p. 56), 20 (p. 3).

Berlin Acad., Mems., 1801 (p. 118).

Monatsbr., 1844 (p. 313), 1873 (p. 362).

Berlin Ast. Jahrb., 1786 (p. 259), 1787 (p. 224), 1789 (p. 214), 1795 (p. 175), 1803 (p. 185), 1805 (p. 113), 1815 (p. 209), 1817 (p. 242), Supp. 4 (p. 67).

Bessel, F. W., Fundamenta Astronomiæ Regiomonti, 1818, p. 308.

Tabl. Regiomont., Introd., p. xi.

Abhandlungen von F. W. Bessel (Engelmann), Leipzig, 1875, vol. 1 (p. 300).

Ast. Nach., 514.

Bologna Ist. Naz. Ital., Mem., vol. 1, 1806, pt. 1.

Bouris, G. C., Ast. Nach., Ergänzungs-Heft, 1849, p. 119.

Brinkley, J., Quantity of the Precession of the Equinoxes, Irish Acad., Roy., Trans., vol. 15 (p. 39).

Elements of Astronomy, 2nd ed. (p. 128).

British Assn. Catalogue, p. 47.

Report, 1873.

Brunnow's Ast. Notices, No. 28.

Cacciatore, N., Palermo Observations, vol. 9, p. 153.

Calandrelli, Sopra i Movimenti propri delle Stelle, Lincei Nuovi, Accad. Pont. Roma, Atti, vol. 10, 1856 (pp. 209, 313).

Sul Movimento proprio di *Sirio*, ditto, vol. 11, 1857 (pp. 19, 91, 156, 197, 240, 299, 355).

Appendice alle Ricerche sopra i Movimenti propri di *Sirio*, ditto, vol. 12, 1859 (pp. 15, 61).

Nuovi Ricerche sul Moto proprio delle Stelle, ditto, vol. 16 (pp. 365, 453).

Cherbourg Soc. Sci. Mémis., vol. 1, p. 332.

Comptes Rendus, *see* Acad. des Sciences.
Conn. des Temps, an 6, 1797 (pp. 203, 463), 1808 (p. 354), 1809 (p. 377), 1831 (p. 120), 1867 (p. 44).
Dorpat Observations, vol. 14.
Dunkin, E., On the Movement of the Solar System in Space, deduced from the Proper Motions of 1167 Stars, Ast. Soc., Roy., Mems., vol. 32.
Edinburgh Observations, 1843, p. ix.
Galloway, T., On the Proper Motion of the Solar System, Phil. Trans., 1847, p. 79.
Geneva, Bibl. Univ., 1859.
Gould's Ast. Jour., vols. 1 (p. 158), 4 (p. 77), 5 (p. 81).
Herschel, W., On the Proper Motion of the Sun and Solar System, Phil. Trans., 1783, p. 247.
On the Direction and Velocity of the Motion of the Sun and Solar System, Phil. Trans., 1805 (p. 233), 1806 (p. 205).
Hornsby, T., An Inquiry into the Quantity and Direction of the Proper Motion of *Arcturus*, Phil. Trans., 1773 (p. 93).
Irish Acad., Roy., Trans., vol. 15, p. 39.
Kazan University, Outchonia Zapiski (Scientific Notes), 1860, p. 47.
Kowalski, Sur les Lois du Mouvement propre des Étoiles du Catalogue de Bradley, Kazan Univ. Outchonia Zapiski, 1860, p. 47.
Lalande, J., Sur le Mouvement particulier propre à différentes Étoiles, Conn. des Temps, 1797, pp. 203, 463.
Table du Mouvement propre des principales Étoiles, Conn. des Temps, 1808, p. 354.
Lincei Nuovi, Accad. Pont. Roma, Atti, vols. 10, 1856 (pp. 209, 313), 11, 1857 (pp. 19, 91, 156, 197, 240, 299, 355), 12, 1859 (pp. 15, 61), 16, 1863 (pp. 365, 453).
Madras General Catalogue, 1844, p. cclvi.
Observations, 1836–1837, p. cxv.
Mädler, J. H., Untersuchungen über die Fixstern-System, Mitau und Leipzig, 1847–48.
Die Eigenbewegungen der Fixsterne, Dorpat Observations, vol. 14.
Die Centralsonne, Dorpat, 1846.
Main, R., Proper Motions of the Stars contained in the Greenwich 12-Year Catalogue of 2156 Stars, Ast. Soc., Roy., Mems., vol. 19.
Proper Motions of Stars of the Greenwich Catalogue of 1576 Stars, Ast. Soc., Roy., Mems., vol. 28.
Maurice, F., *see* Prevost.
Mayer, Christian, Vertheidigung neuer Beobacht. Gruendliche von Fixstern Trabanten, Mannheim, 1778.
De novis in Cœlo Sidereo Phænomenis, Mannheim, 1779.
Philadelphia Soc. Trans., vol. 2, 1786, p. 217.
Mayer, Tobias, Opera Inedita, vol. 1, 1775, p. 75.
Modena, Soc. Ital., Mems., vol. 23, p. 54.
Moesta, C. G., *see* Santiago Observations.
Oeltzen, W., Eigene Bewegungen von Fixsternen, abgeleitet aus der Vergleichung der *Histoire Céleste* mit den Argelanderschen nördlichen Zonen, Vienna K. K. Acad. Sitz., vol. 16, p. 540.

Peters, C. A. F., Ueber Prof. Mädler's Untersuchungen über die eigenen Bewegungen der Fixsterne, Petersb., St., Acad. Imp. Sci., Bull., vol. 7, 1849, Nos. 12 and 13.

Ueber die eigene Bewegung des *Sirius*, Ast. Nach., 745 to 748.

Petersburg, St., Acad. Imp. Sci., Mems., vol. 5, 1844, p. 17.

Mems., Divers Savants, vol. 3, p. 561.

Bull., vol. 2, 1837, Nos. 8, 9; vol. 10, No. 9; vol. 7, 1849, Nos. 12, 13.

Philadelphia Soc. Trans., vol. 2, 1786, p. 217.

Piazzi, G., Saggio sui Movimenti proprii dell Fisse, Bologna Ist. Naz. Ital., Mem., vol. 1, 1806, part 1.

Prevost, P., and Maurice, F., Mémoire sur le Mouvement propre de quelques Étoiles de 1756 à 1797, Berlin Acad. Méms., 1801, p. 118;

Proctor, R. A., Royal Soc. Proc., vol. 18, p. 169.

Essays on Astronomy, 1872.

Quetelet, E., Essai sur le Mouvement propre en Ascension droite de quelques Étoiles, Belgium, Acad. R., Méms., vol. 32.

Robinson, T. R., Armagh Catalogue, p. xxxiii.

Royal Society, Phil. Trans., 1718 (p. 736), 1773 (p. 93), 1783 (p. 247), 1805 (p. 233), 1806 (p. 205), 1815 (p. 386), 1823 (p. 529), 1847 (p. 79), 1868 (p. 529).

Proc., vols. 18 (p. 169), 20 (p. 379).

Safford, T. H., On the Solar Motion in Space, and the Stellar Distances, American Acad. Proc., New Series, vols. 2 (p. 82), 3 (pp. 52, 210).

Santiago Observations, vol. 2, Dresde, 1875, p. 132.

Scaramucci, D., Di alcuni Effetti del Moto orbitale del Sole, Firenze, 1841.

Silliman's American Jour., 2nd Series, vols. 2 (p. 433), 49 (p. 436).

Smithsonian Report, 1859, p. 220.

Stone, E. J., Proper Motions of the Stars in the Greenwich 7-Year Catalogue of 2022 Stars, Ast. Soc., Roy., Mems., vol. 33.

Proper Motions of 406 Southern Stars, Ast. Soc., Roy., Mems., vol. 42.

Struve, O., Bestimmung der Constante der Präcession, 1842, Petersb., St., Acad. Imp. Sci. Mems., vol. 5, 1844, p. 17.

Struve, W., Stellarum Duplicium et Multiplicium Mensuræ Micrometricæ, Petropoli, 1837, p. c.

Stellarum Fixarum imprimis Duplicium et Multiplicium Positiones Mediæ, Petropoli, 1852, pp. cxlii, ccv.

Études d'Astronomie stellaire, St. Pétersbourg, 1847.

Student, The, vol. 5.

Theory of the Sun's Orbit, by Anaxagoras, London, 1834.

Triesnecker, Vienna Ephem., 1792.

Vienna, K. K. Acad. Sitz., vol. 16, p. 540.

Zach, Baron de, Monat. Corresp., vols. 10 (p. 25), 16 (pp. 275, 365), 23 (p. 38), 27 (pp. 335, 383), 28.

6. PARALLAX AND DISTANCE OF STARS.

Acad. des Sciences, Méms., 1699 (p. 177), 1717 (p. 256), 1739 (p. 358).

Comptes Rendus, vols. 7 (p. 785), 10 (p. 703), 19 (p. 400), 23 (pp. 440, 1074), 25 (pp. 136, 144), 26 (pp. 64, 69, 72), 30 (pp. 68, 117, 413), 35 (pp. 741, 859), 56 (p. 268), 66 (p. 664).

Airy, G. B., On the Parallax of α *Lyræ*, Ast. Soc., Roy., Mems., vol. 10.
Assas-Montdardier, Conn. des Temps, 1831, p. 120.
Ast. Gesell. Pub., No. 11.
Ast. Nach., Nos. 365, 366, 396, 401, 402, 486, 498, 512, 567, 610, 685, 759, 841 to 844, 865, 866, 884, 1010, 1147, 1176, 1210, 1373, 1403, 1411, 1416, 1688 (to vol. 85), Ergänzungs-Heft, 1849 (p. 53).
Ast. Reg., 1867 (p. 253), 1875 (p. 272).
Ast. Soc., Roy., Mems., vols. 1, 2, 10, 11, 12, 20, 21, 24, 28.
Mon. Nots., vols. 4 (pp. 91, 152, 168), 5 (pp. 5, 51, 171, 182), 7, (p. 219), 9 (p. 79), 10 (pp. 59, 124), 11 (p. 131), 12 (pp. 119, 174), 13 pp. 74, 130), 14 (pp. 49, 159), 16 (p. 163), 18 (p. 289), 20 (p. 252), 23 (pp. 74, 172), 28 (p. 2), 33 (p. 52), 34 (p. 339) to vol. 35.
Auwers, A., Parallaxen-Bestimmung mit dem Königsberger Heliometer, Ast. Nach., 1411.
Bestimmung der Parallaxe des Sterns 34 Groombridge, Berlin Acad. Abhand., 1867.
Bestimmung der Parallaxe von 61 *Cygni*, Berlin Acad. Abhand., 1868.
Berlin Acad. Monatsber., August, 1874.
Belgium, Acad. Roy., Bull., 2nd Series, vol. 13, p. 232.
Berlin Acad., Abhand., 1867, 1868.
Monatsber., 1874, p. 569.
Ast. Jahrb., 1794 (p. 246), 1796 (p. 113), 1805 (p. 197), 1814 (p. 226), 1815 (p. 209), 1819 (p. 215).
Bessel, F. W., Fundamenta Astronomiæ Regiomonti, 1818, p. 110.
Ueber die Parallaxe von α *Herculis*, Briefw. mit Olbers, vol. 1, p. 47.
Ueber die Parallaxe von 61 *Cygni* und μ *Cassiopeæ*, Königsberg Observations, 2 Abth., p. v.
Bestimmung der Entfernung des 61 Sterns des Schwans, Ast. Nach., 365, 401.
Briefwechsel mit Olbers, vol. 1, pp. 47, 197, 200, 220, 399, 406, 435, 448.
Zach's Monat. Corresp., vols. 19 (pp. 183, 245), 26 (p. 148).
Abhandlungen von F. W. Bessel (Engelmann), Leipzig, 1876, vol. 2, pp. 204, 206, 207, 213, 217.
Messung der Entfernung des 61 Sterns im Sternbilde des Schwans, Schumacher's Jahrbuch, 1839, p. 1.
Böhm. Gesell. Abhand., vol. 4, p. 621.
Brinkley, J., On the Parallax of certain Fixed Stars, Phil. Trans., 1818, p. 275, and 1821, p. 327.
On the Parallax of α *Lyræ*, Phil. Trans., 1824, p. 471, and Ast. Soc., Roy., Mems., vol. i., p. 329.
Irish Soc., Roy., Mems., vols. 12 (pp. 33, 119), 14 (p. 5).
British Assn. Rep., 1837 (p. 3), 1871 (p. 34).
Brunnow, F., Determination of the Parallax of α *Lyræ* and 61 σ *Draconis*, Dunsink Observations, part 1, 1870.
Investigation of the Parallax of 1830 Groombridge, 61 σ *Draconis*,

85 *Pegasi*, Bradley 3077, and *α Lyræ*, Dunsink Observations, part 2, 1873.

Cesaris, Angelo, Sulla Parallasse delle Stelle, Milano Effem. Ast., 1807, App., p. 59.

Chiminello, V., Dell annua Parallasse di α della *Capra*, Modena Soc. Ital., vol. 14, 1809, p. 1.

Clairaut, Sur la Manière la plus simple d'examiner si les Étoiles Fixes ont une Parallaxe et de la déterminer exactement, Acad. des Sciences, Méms., 1739, p. 358.

Comptes Rendus, *see* Acad. des Sciences.

Conn. des Temps, 1808 (p. 432), 1819 (p. 383), 1831 (p. 120).

Copenhagen, Selsk. Scrif., vol. 6, p. 129.

Dollen, W., Ueber Dr. Wichmann's Bestimmung der Parallaxe des Argelanderischen Sterns, Petersb., St., Acad. Imp. Sci. Bull., vol. 13, 1855, Supp.

Doppler, C., Beiträge zur Fixsternenkunde, Böhm. Gesell. Abhand., vol. 4, p. 621.

Dorpat Observations, vols. 2 (p. 199), 3 (p. li).

Dufour, C., Vaudoise Soc. Bull., vol. 10, 1868, p. 1.

Edinburgh Phil. Jour., New, vol. 48, p. 297.

N.S., vols. 7 (p. 107), 10 (pp. 325, 361).

Fennicæ Soc. Sci. Acta, vol. 7, 1863, pp. 373, 383.

Fockens, G. R., Commentatio Astronomica, De Annua Stellarum Parallaxi, Lugduni Batavorum, 1835.

Galilei, G., Opera, 1744, vol. 4.

Geneva, Bibl. Univ., 1850, 1863.

Gould's Ast. Jour., vol. 4, p. 152.

Greenwich Observations, 1811 (p. xxvi), 1816 (p. 371).

Grunert, Ast. Nach., 884.

Gylden, N., Neue Berechnung des *Sirius* Parallaxe aus den am Cap der Guten Hoffnung angestellten beobachtungen, Petersb., St., Imp. Sci. Bull., vol. 7, p. 365.

Henderson, T., On the Parallax of *α Centauri*, Ast. Soc., Roy., Mems., vols. 11, 12.

On the Parallax of *Sirius*, ditto, vol. 11.

Herschel, J. F. W., On the Parallax of the Fixed Stars, Phil. Trans., 1826, p. 266.

Herschel, W., On the Parallax of the Fixed Stars, Phil. Trans., 1782, p. 82.

Hooke, R., Attempt to prove the Motion of the Earth, London, 1674, p. 11.

Horrebow, C., Afhandling om Fixstiernernes Distance fra Jorden, Copenhagen Selsk. Scrif., vol. 6, p. 129.

De Parallaxi fixarum annua ex rectascensionibus quam post Rœmerum et Parentem ex propriis observationibus, Havniæ, 1747.

Horrocks, J., Opera Posthuma, Londini, 1673, p. 59.

Intellectual Observer, The, vol. 3, p. 454.

Irish Acad., Roy., Trans., vols. 11 (p. 23), 12 (pp. 33, 119), 14 (p. 5).

Königsberg Observations, vols. 24 (p. 79), 30 (p. 25), 35 (p. 254).

Krueger, A., Ueber die Parallaxe des Sterns LL 21258, Fenn. Soc. Sci. Acta, vol. 7, 1863, p. 373.
Ueber die Parallaxe des Sterns Oeltzen-Argelander 17415–6, Fenn. Soc. Sci. Acta, vol. 7, 1863, p. 383.
Bestimmung der Parallaxe des Doppelsterns 70 *p Ophiuchi*, Ast. Nach., 1210, 1403.
Lindenau, Zeitschrift für Astronomie, vol. 2.
Lindhagen, D. G., Petersb., St., Acad. Imp. Sci. Mems., vol. 7, 1853, p. 323.
Long, Astronomy, Cambridge, 1742, vol. 1, p. 322.
Lundahl, De Numeris Nutationis, Helsingfors, 1842.
Maclear, T., Determination of the Parallax of α^1 and α^2 *Centauri*, Ast. Soc., Roy., Mems., vol. 20.
Investigation of the Parallax of β *Centauri*, Ast. Soc., Roy., Mems., vol. 21.
Madras Observations, 1850–1852, Appendix.
Mädler, J. H., Untersuchungen über die Fixstern-System, vol. 2, p. 194.
Main, R., On the Present State of our Knowledge of the Parallax of the Fixed Stars, Ast. Soc., Roy., Mems., vol. 12.
Maskelyne, A Proposal for Discovering the Annual Parallax of *Sirius*, Phil. Trans., 1760, p. 889.
Milano Effem. Ast., 1807, App. (p. 59), 1865, App. (p. 52).
Modena, Soc. Ital., vols. 12, 1805 (p. 40), 14, 1809 (p. 1).
Moesta, Ast. Nach., 1688.
Peters, C. A. F., Ueber Bessel's Bestimmung der Parallaxe von 61 *Cygni*, Ast. Nach., Ergänsungs-Heft, p. 53.
Recherches sur la Parallaxe des Étoiles Fixes, Petersb., St., Acad. Imp. Sci. Mems., vol. 7, 1853.
Ueber die Parallaxe des Argelander'schen Sterns, Ast. Nach., 865.
Petersb., St., Acad. Imp. Sci., Mems., vol. 7, 1853, pp. 1, 323, 357.
7th Series, vol. 1, 1859, No. 1.
Bull., vol. 10 (No. 9).
vols. 8, 1850 (Nos. 4, 15), 13, 1855 (No. 18, Supp.), 14, 1856 (No. 15).
vol. 7 (p. 365).
Piazzi, G., Ricerche su la Parallasse annua di alcune delle principale Fisse, Modena, Soc. Ital., vol. 12, 1805, p. 40.
Plana, Mémoire sur les Formules propres à déterminer la Parallaxe annuelle des Étoiles simples ou optiquement doubles, Turin, Acad. R., Mems., 1859 (p. 503), Ast. Nach., 1176.
Pond, J., On the Parallax of the Fixed Stars, Phil. Trans., 1817 (pp. 158, 353), 1818 (p. 477), 1823 (p. 53).
Radcliffe Observations, 1853 (p. xxxii), 1855 (p. xvii), 1860 (p. 167).
Riccioli, P. J. B., Almagestum Novum, 1653, tom. 1, p. 414.
Royal Society, Phil. Trans., 1674 (p. 90), 1693 (p. 844), 1694 (p. 101), 1720 (p. 1), 1728 (p. 637), 1760 (p. 889), 1767 (p. 234), 1782 (p. 82), 1784 (p. 35), 1810 (p. 204), 1817 (pp. 158, 353), 1818 (pp. 275, 477), 1821 (p. 327), 1823 (p. 53), 1824 (p. 471), 1826 (p. 266), 1827 (p. 126), 1851 (p. 333).

Schiaparelli, G. W., Sopra le Distanze delle Stelle Fisse dei varj ordi
splendori, Milano Effem. Ast., 1865, App., p. 52.
Schubert, Berlin Ast. Jahrb., 1796, p. 113.
Schumacher's Jahrbuch, 1839, p. 1.
Silliman's American Jour., 1st Series, vol. 36 (p. 200), 2nd Series, vol
(p. 457), 40 (p. 190).
Stockholm, Vetensk. Acad., Handlingar, 1750 (p. 241), 1751 (p. 1).
Struve, Otto, Mémoire sur l'Évaluation numérique de la Constante d
Précession des Équinoxes.
Nouvelle Détermination de la Parallaxe de l'Étoile Groombr
1830, Petersb., St., Acad. Imp. Sci., Bull., vol. 8, 1850, No.
Narratio de Parallaxi Stellæ *α Lyræ*, Petropoli, 1852.
Petersb., St., Acad. Imp. Sci., Bull., vol. 13, 1855, No. 18.
Sur les Parallaxes d'*α Aurigæ*, *η Cassiopeæ*, et *μ Cassiopeæ*, Pete
St., Acad. Imp. Sci., Bull., vol. 14, 1856, No. 15.
Nouvelle Détermination de la Parallaxe annuelle des Étoiles *α L*
et 61 *Cygni*, Petersb., St., Acad. Imp. Sci., Mems., 7th Se
vol. 1, 1859.
Struve, F. G. W., Dorpat Observations, vols. 2 (p. 199), 3 (p. li).
Stellarum Duplicium et Multiplicium Mensuræ Micrometr
Petropoli, 1837 (p. clxii).
Additamentum in Mensuras Micrometricas, Petersb., St., Acad. I
Sci., Mems., vol. 4, 1841, p. 353 *a*.
Études d'Astronomie stellaire, St. Pétersbourg, 1847.
Petersb., St., Acad. Imp. Sci., Mems., vol. 4, 1841, p. 353; B
vol. 8, 1850, No. 15.
Ueber die Parallaxe des Sterns *α Lyræ*, Ast. Nach. 396.
Turin, Acad. R., Mems., vol. 18, 1859, p. 503.
Vaudoise Soc., Bull., vol. 10, 1868, p. 1.
Wallis, Opera Mathematica, vol. 3, p. 705.
Wargentin, P., Om Stjernornas Parallaxis och Aberrationer, Stockh
Vetensk. Acad., Handlingar, 1750 (p. 241), 1751 (p. 1).
Wichmann, M., De Parallaxi Stellæ Argelandriæ (1830 Groombridge)
sertatio, 1847.
Ast. Nach., 841 to 844, 1010.
Winnecke, F. A. T., Bestimmung der Parallaxe des zweiten Argelander's
Sternes, Ast. Gesell. Pub., No. 11, 1872.
Zach, Baron de, Monat. Corresp., vols. 8 (p. 518), 18 (p. 401), 19 (pp.
183, 234, 259).
Corresp., vol. 10 (p. 476).

7. STAR-SPECTRA.

Acad. des Sciences, Comptes Rendus, vols. 57 (p. 71), 58 (p. 795),
(p. 543), 62 (p. 591), 63 (pp. 324, 364, 621), 64 (pp.
738, 774), 65 (pp. 292, 389, 562, 979), 66 (pp. 124, 398),
(p. 373), 68 (pp. 358, 761, 959, 1086, 1470, 1519, 1545),
(pp. 39, 163, 551, 1053), 71 (p. 252), 75 (p. 655).

Arrest, H. L. D', Undersøgelser over de Nebulose Stjerner, Kjøbenhavn, 1872. Ast. Nach., 2009, 2016; Ast. Reg., 1875 (pp. 257, 290).
Ast. Nach., Nos. 1405, 1408, 1577, 1585, 1586, 1608, 1612, 1737, 1863, 1885, 1908, 1969, 2000, 2009, 2016, 2032, to vol. 85.
Ast. Reg., 1866 (pp. 253, 280, 290), 1867 (pp. 18, 34, 40), 1868 (p. 155), 1872 (p. 164) 1874 (pp. 52, 243), 1875 (pp. 208, 257, 290).
Ast. Soc., Roy., Mon. Nots., vols. 23 (pp. 100, 179, 188), 24 (p. 218), 25 (pp. 60, 153, 155), 26 (pp. 214, 274, 297), 28 (p. 196), 32 (p. 359), 34 (p. 267) to vol. 35.
Belgium, Acad. Roy., Bull., vol. 37.
Brit. Assn. Rep., 1864 (p. 12), 1868, (pp. 140, 152), 1871 (p. 34).
Bulletino Meteorologico, 1866.
Comptes Rendus, *see* Acad. des Sciences.
Donati, G. B., Intorno alle Strie degli Spettri Stellari, Florence, Museo Fis. R., Annali, vol. 1, 2nd Series.
Edinburgh Jour. Sci., Brewster's, vol. 8, p. 7.
Edinburgh Observations, 1860–1870 (R. 121).
Florence, Museo Fis. R., Annali, vol. 1, 2nd Series.
Geneva, Bibl. Univ., 1865, 1873.
Huggins, W., and Miller, W. A., On the Spectra of some of the Fixed Stars, Phil. Trans., 1864, p. 413.
Huggins, W., Further Observations on the Spectra of some of the Stars and Nebulæ, Phil. Trans., 1866, p. 381.
Further Observations on the Spectra of some of the Stars and Nebulæ, Phil. Trans., 1868, p. 529.
Intellectual Observer, The, vols. 3 (p. 338), 6 (p. 387), 9 (p. 382), 10 (p. 386).
Ital. Soc., Mem., Firenze, 3rd Series, vol. i., 1867, part 1.
Janssen, Lincei Nuovi, Accad. Pont. Roma, Atti. vol. 16, 1863, pp. 84, 264.
Jour. Sci., Quar., 1866 (p. 376), 1869 (p. 209).
Leipzig, Gesell. Bericht., 1869 (p. 70), 1872, 1873.
Lincei Nuovi, Accad. Pont. Roma, Atti, vols. 16, 1863 (pp. 84, 264), 21, 1868 (pp. 52, 137), 22, 1869 (p. 124), 1872.
Phil. Mag. Lond. and Edin., 4th Series, vols. 11 (p. 448), 29 (p. 489), 31 (pp. 405, 475, 515), 35 (pp. 78, 155, 241, 400), 36 (p. 394), 38 (p. 360).
Poggendorf, Ann. Phy. Chem., vols. 117 (p. 654), 131 (p. 156).
Royal Society, Phil. Trans., 1864 (p. 413), 1866 (p. 381), 1868 (p. 529).
Proc., vols. 12 (p. 444), 13 (p. 242), 14 (p. 39), 16 (pp. 382, 417, 451), 17 (p. 58), 20 (p. 379).
Secchi, A., Romano Coll. Osser., Mem., 1860–1863.
Ast. Nach., 1405.
Comptes Rendus, vols. 57 (p. 71). 60 (p. 543), 62 (p. 591), 63 (pp. 324, 364, 621), 64 (pp. 345. 738, 774), 65 (pp. 389, 562, 979), 66 (pp. 124, 398), 68 (pp. 358, 761, 959, 1086), 71 (p. 252), 75 (p. 655).
Sugli Spettri Prismatici delle Stelle Fisse, Ital. Soc. Mem., Firenze 3rd Series, vol. 1, 1867.

Sugli Spettri Prismatici dei Corpi Celesti, 1868, 1870.
Les Decouvertes Spectroscopiques, Giornale Arcadico, Rome, vol. 1865.
Lincei Nuovi, Accad. Pont., Roma, Atti, vol. 21, 1868, pp. 52, 13;
Silliman's American Jour., 2nd Series, vols. 35 (p. 71), 36 (p. 154), (p. 73), 42 (p. 389), 49 (p. 58); 3rd Series, vols. 2 (p. 1, 5 (p. 75).
Vogel, H. C., Leipzig Gesell. Ber., 1873.
Bothkamp Observations, vol. 2 (p. 9).
Zöllner, F., Leipzig Gesell. Ber., 1869, p. 70.
Silliman's Amer. Jour., 2nd Series, vol. 49, p. 58.
Phil. Mag., vol. 38, p. 360.

APPENDIX.

The following References, extracted principally from the Catalogue of t Poulkova Library, are to works which I have been unable to find, or wh have unintentionally escaped notice.

DOUBLE STARS.

Fuss, Réflexions sur les Satellites des Étoiles, Petrop. Sci. Acad. 1780.
Brandes, Auszug aus Herschel's Mikrometrischen Messungen der Doppelster
Harding, Ast. Ephem. 1833. Göttingen.
Littrow, Die Doppelsterne, Wien, 1835.
Zwei Anzeigen von W. Struve Mens. Microm., Berliner. Staats Zeitung, 18; 1838.
Philadelphia, Soc. Trans. 1839.
Mädler, Ueber die Fixsternsyteme, Rede, Berlin, 1845.

VARIABLE STARS.

Busch, Von dem Cometen welcher in diesem 1572 Jar. in dem Monat Nove bris erscheinen, Norimberg, Augspurg, 1572.
Camerarius, De Nova Stella Cassiopeiae, Francofurti-a-V. 1573.
Gemma, De Naturæ Divinis Characterismis, Libri 2, Antverpiæ, 1578.
Stellæ Peregrinæ, Lovanii, 1573.
Leovitius a Leonicia, De Nova Stella, Lavingæ, 1573.
Misnerus, Beschriebunge des Cometen a. 1572, Erffurdt, 1573.
Nolthius, Observatio des Newen Cometen, Erffurdt.
Brahe, Tycho, De Nova Stella anno 1572.
Contemplatio Mathematica, Hafniæ, 1573.
Hagecius ab Hayck, Dialexis de Nova Stella, Francofurti-a-M. 1574.
" " " " Pragæ, 1576 and 1577.
Chytræus, De Stella Inusitata et Nova, Rost, 1577.

Herlicius, Astronomische Erklerung des Neuen Sterns, Stettin, 1604.
Krabbe, Cometa so anno 1604 erscheinen, Erffurdt, 1604.
Khepplern and Roeselinum, Bericht von Newenstern 1604, Amberg., 1605.
Buttuerus, Cometen Stundbüchlein, Eissleben, 1605.
Crügerus, Theoremata Exegetica, Dantisci, 1605.
Mollerus, Von dem Newen Cometstern, Eissleben, 1605.
Molerius, De Sydere Novo, 1606.
Nagelius, Interpretation des Neuen Wunder-sterns, Argeliæ, 1619.
Longomontanus, Astronomia Danica (Appendix), Amsterdami, 1640.
Liceti, De Novis Astris, Venetiis, 1623.
Claramontii, De Tribus Novis Stellis, Cæsenæ, 1628. 4.
Schnitzlerus, De Stellis Fixis Novis, Witteburg, 1659.
Libavius, De Cometa a. 1604, Amstelædami, 1665.
Bullialdus, De Stella Nova in Collo *Ceti*, Parisiis, 1667.
Tacquet, Opera Mathematica, Antverpiæ, 1669.
Kirch, Von dem Newen Wunder-Stern, Leipzig, 1678.
Ephem. Mot. Cælest., 1681–1692.
Berlin Akad., 1710.
Waechtter, De Stellis Novis, Vitembergæ, 1691.
Elvius, De Stellis Novis, Upsalis, 1704.
Liebknecht, Stella Salvatoris, Jenæ, 1705.
Stella noviter detecta, Gissæ, 1723.
Stellæ Ludovicianæ noviter detectæ consideratio, Gissæ, 1723.
Wideburgius, De Stellis Mutabilibus, Jenæ, 1739.
Strömer, De Stellis Novis, Strengnesiæ, 1755.
De Stella quae Magis Nato Christo apparuit, Regiomonti, 1766.
Göttingisches Magazin, 1781–1782.
Huber, Acta Helvetica, 1787.
Harding, Ast. Ephem. 1830–1835, Göttingen.

NEBULÆ AND CLUSTERS.

Cremonini, De Via Lactea, Venetiis, 1613.
Raschius, De Via Lactea, 1619.
Bullialdus, De Nebulosa in *Andromeda*, Parisiis, 1667.
Fendt, De Galaxia, Habniæ, 1707.
Mullerus, De Galaxia, Altorfii, 1713.
Melander, De Cælo Fixarum, Upsaliæ, 1760.
Bode, Beiträge zur den Neuester Astronomische Entdeckung.
Harding, Ast. Ephem. 1832–1835.
Encke, Betrachtungen über die Anordnung des Sternsystems, Berlin, 1844.
Wichmann, Königsberg Nat. Unterh. 2, 1850.
Bern, Nat. Gesell. Mitt., 1850, 1851, 1853.
Mädler, Beiträge zur Fixsternkunde, Haarlem, 1856.

PROPER MOTIONS OF STARS.

Agardh, De Motu Systematis Solaris Progressivo, Lundæ, 1841.

PARALLAX AND DISTANCE OF STARS.

Horrebow, Copernicus Triumphans, Havniæ, 1727.
Basis Astronomiæ, Havniæ, 1735.
Manfredius, De Annuis Inerrantium Stellarum Aberrat. Bononiæ, 1729.
Celsius, De Parallaxi Stell. Fix. Ann., Upsaliæ, 1730.
Wideburg, De Parallaxi Orbis Ann., Jenæ, 1746.
Ditto, Commentatio, Jenæ, 1747.
Regner, De Conatis ad Parall. Ann. Upsaliæ, 1800.
Lundstedt, De Aberratione et Parallaxi Annua, Upsaliæ, 1821.
Königsberg, Nat. Unterh. vol. i.
Blomstrand, De Fide quae sit Astronomorum in Parallaxi Fixarum, Lun
1850.

On the Visibility of the Unilluminated Portion of the Disk of Ven

By William Lassell, Esq., LL.D., F.R.S.

(*Extract from a Letter to E. Dunkin, F.R.S., Secretary.*)

The sky being clear on both the 12th and 13th of July observed *Venus* during a considerable part of the afternoons both days, with the two-foot Equatoreal powers 155 and 219. call the image a *crescent* is almost a misnomer; it might rath especially on the 13th, be called a sharp, brilliant, semi-circu *hair*. The cusps appeared scarcely to reach the ends of a d meter—certainly not beyond in my estimation. As it has be said that under such circumstances the unilluminated part of t disk has been visible or traceable, I looked most carefully such an appearance on both occasions, without being able to p ceive any whatever. On the 13th I applied the micromet hiding all but the ends of the cusps behind one of the jaws, a endeavoured to divest myself of all prejudice which might ar from my belief that such could not be visible. The result, ho ever, was entirely negative. I could not gain even an impress of any difference of brightness or colour of the sky included tween or beyond the cusps, and that surrounding or adjacent. the latter day I could not continue my observation so long, the fierce sun shining down the inside of the tube soon occasio a disturbance, which greatly impaired the precision of the ima

Ray Lodge, Maidenhead,
1876, 19 *July*.

ERRATA.

p. 350, line 7 from bottom, for *with* read *With*.
p. 351, line 4, for *make* read *made*.
p. 358, line 4 from bottom, for *developed* read *depended*.
p. 359, line 20, for $\Delta\delta l$ read Δl.
p. 359, line 32, read "const. of $k = k_0 = 0''.10$."
p. 361, lines 17 and 18, *dele* the sign — before $1''.50$.

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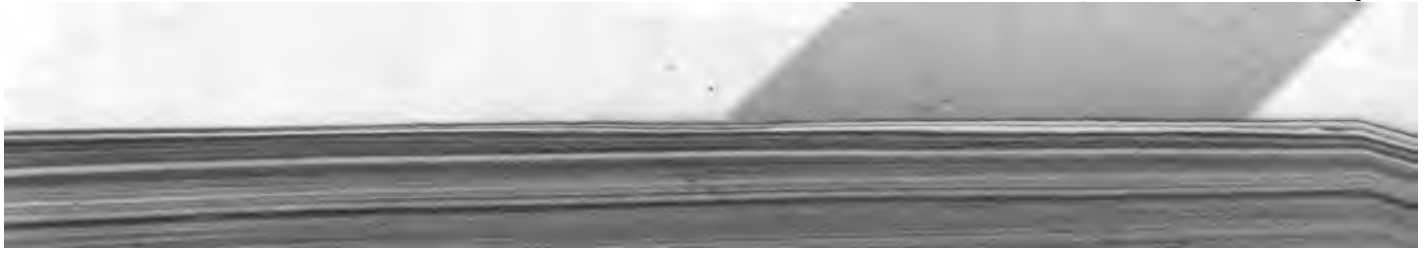

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